EXTENDED PROJECT FILE

FINAL PROJECT TITLE: To what extent do the use of Artificial Intelligence systems in Medicine contribute to the socio-economic condition of society?

PROJECT FORMAT/TYPE: Dissertation

LEARNER NAME: Philip Mortimer

LEARNER NUMBER: _____

CENTRE NAME: Gower College Swansea

CENTRE NUMBER: 68815

(To be completed by the Supervisor after final assessment)

Final Marks	
AO1	
AO2	
AO3	
AO4	
TOTAL	

EXTENDED PROJECT LEARNER DECLARATION

Centre No: 68815 **Centre Name:** Gower College Swansea

Learner's full name: Philip Mortimer **Learner No:**

Extended Project Title: **To what extent do the use of Artificial Intelligence systems in Medicine contribute to the socio-economic condition of society?**

Extended Project Format/Type: Dissertation *(dissertation/artefact/design/performance*

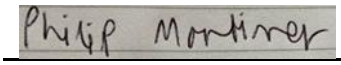
Notice to Learner
The work you submit for assessment must be your own. If you copy from someone else, allow another learner to copy from you, or if you cheat in any other way, you may be disqualified from at least the subject concerned.

The final Extended Project submission MUST include the following:

Extended Project Proposal & Title
Extended Project Records
Extended Project Outcome
Extended Project Presentation Witness Statement
Extended Project Plan
Extended Project Meetings with Supervisors
Extended Project Presentation
Extended Project Supervisor Final Assessment Mark Sheet

Declaration by Learner

I have read and understood the Notice to the Learner (above). I have produced the attached work without assistance other than that which my teacher has explained is acceptable within the specification. I have not submitted any of this work for other courses/subjects.

Learner's Signature:  **Date:** **31/01/2021**

Declaration by Teacher

I confirm that the Learner's work was conducted under the conditions set out in the specification and that it has not been submitted for other course/subjects.
I have authenticated the Learner's work and satisfied that to the best of my knowledge the work produced is solely that of the Learner.

Please note what other KS5 subjects/qualifications the student is undertaking alongside the EPQ.

1.	2.	3.	4.

Teacher's Signature: **Date:**

EXTENDED PROJECT FILE

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PART A LEARNER RECORDS	FORM NUMBER	Completed *(Tick or date)*
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Extended Project Record **(i) Project Plan and Change to Plan** **(ii) Record & Review of Teaching and Learning Programme** **(iii) Record & Review of Individual Progress** **(iv) Record of Meetings with Supervisors** **(v) Records of Any Additional Meetings with Supervisors**	 **(EPF2a & 2b)** **(EPF 2c)** **(EPF 2d)** **(EPF 2e)**	
Extended Project Outcome	**(EPF 3)**	
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Extended Project Presentation Witness Statement	**(EPF 5)**	
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EXTENDED PROJECT

Section A

Learner Records

N.B. All boxes in the different sections are expandable therefore please expand, as appropriate.

These forms should be completed electronically

EPF 1	EXTENDED PROJECT PROPOSAL & TITLE APPROVAL FORM	

NOTE: Project Titles must be approved at least 6 months before the final submission date.

Learner Name: Philip Mortimer	**Learner Number:**
Centre Name: Gower College Swansea	**Centre Number: 68815**

FIRST STEPS: Before you decide on a project topic, you need to think carefully about your ideas and consider whether your project is viable.

STAGE 1 - THINKING ABOUT YOUR EXTENDED PROJECT

What topics might you choose for your Extended Project?

For my extended project qualification, I have considered the following topics:
1.The potential future developments of Artificial Intelligence, considering its current uses.
2.The real-world applications of quantum mechanics.
3.What quantum mechanics is and how it was discovered.
4.The implications of quantum computing on society, especially cybersecurity.
5.How pi was found and whether it is irrational.
6.The validity of the theory of determinism, especially when considering the seeming randomness of quantum mechanics and radioactive decay.

2. Briefly explore each of the possible topics you have listed in question 1 considering the positive aspects and potential challenges.

"The potential future developments of Artificial Intelligence, considering its current uses.". Currently artificial intelligence (AI) is used globally and impacts much of our lives. As computer hardware develops, so does the potency of AI, begging the question as to its potential future applications and whether it may even be comparably intelligent to a human. From my initial research, I know that AI is thoroughly researched and constantly evolving topic, thus making it a viable topic to evaluate for an extended piece of writing. Whilst one can track the development in computer programs over time, it may be too difficult to produce a judgement on future developments due to the inherent subjectivity of speculation. In my initial research, I found many sources which shows to me that there is also enough scope for source analysis with this topic. (https://medium.com/datadriveninvestor/evolution-of-ai-past-present-future-6f995d5f964a). However, sources such as this one are arguably too opinionated in certain regards, which suggest that focusing on past and current uses of AI would be wise if I choose this topic. It is also important to note that the topic may have too large of a scope to thoroughly answer, so I may wish to consider formulating a more specific research question if I choose this topic. On the other hand, I think this topic is a highly interesting one that could result in a quality dissertation, particularly as it is arguably very important to the development of society as a whole. Following feedback on my title, I have decided that this topic area is too large to realistically write an EPQ on. Furthermore, the evaluation of future developments of AI is, on reflection, something that doesn`t facilitate a factual and researched dissertation. However, I certainly think there is great merit in evaluating the current uses of AI. I could use this element of the idea to

evaluate AI`s applications in the real world. For example, I could focus on the economic impact or medicinal impact or the impact of data analysis on security. Essentially the “current uses” element of this has many potential questions that would lead to a high-quality project.

“The real-world applications of quantum mechanics.”. The bizarre phenomena, known as quantum mechanics, that occur have led scientists to create many concepts that could massively impact society. For example, scientists have already managed to get a particle to “teleport” instantly over 8.2 km, which could one day be used to create a “quantum internet” (https://www.bbc.co.uk/news/science-environment-37408013). Other uses include quantum computing and many strange mechanics such as quantum teleportation, tunnelling, levitation and superposition. There is certainly a lot of fascinating things to talk about with this topic, however I feel that the topic lacks cohesion and would probably just to boil down to many individual examples being referenced without much of a link between them. This topic is certainly at the forefront of research and has many sources written on it, I feel that I probably lack the understanding to make a good piece on the field. I am also uncertain as to whether it can full satisfy the scope of the extended project qualification due to the lack of possible analysis in this area.

“What quantum mechanics is and how it was discovered.”. Quantum mechanics is an advanced field of physics which is used to describe the behaviour of things such as photons on a miniscule level. The term covers a whole range of behaviours that seem to directly clash with classical physics, such as photons exhibiting light and wave properties simultaneously. Naturally, there is an extremely large amount of research about the topic, thus allowing adequate source analysis. However, I feel that the field may be too advanced to do justice to as it is extremely difficult to grasp some of the concepts proposed (https://quantumphysicsmadesimple.com/introduction-for-beginners) and hence I would need to spend far too much time accumulating a rudimentary knowledge of the subject. Due to my lack of knowledge, I would be unable to cite multiple different viewpoints and then conclude as to which one is more accurate. Furthermore, I would need to focus the topic to something more specific to ensure that I analyse and reach a judgement on the topic.

“The implications of quantum computing on society, especially cybersecurity.”. In a traditional computer system, information is stored as either a 1 or 0. However, due to quantum entanglement and quantum superposition “qubits” (in combination) have the potential to be exponentially more powerful than traditional hardware as they can store more states and can be “entangled” which allows a connected particle to change position instantly if the other is changed (https://www.extremetech.com/extreme/284306-how-quantum-computing-works). This field is a massively interesting one and combines my passion for maths, physics and computing and hence it would be a good topic. The rapidly evolving nature of the field (https://www.newindianexpress.com/business/2019/oct/29/googles-striking-quantum-computer-feat-is-the-world-ready-for-what-comes-next-2054338.html) ensures that there is lots of research online, thus facilitating a project that satisfies the criteria of the EPQ. However, I could be limited by the fact that the field is very complicated and involves quantum mechanics which is certainly not fully understood yet. Consequently, it would be difficult for me to fully evaluate its impact on society. I am also unconvinced that the topic is of large enough scope to facilitate a 5000-word piece that thoroughly covers my topic.

“How pi was found and whether it is irrational.”. Pi is the ratio between the circumference and diameter of a circle and is used everywhere. However, its origins and even current day attempts to refine the value are interesting. One of the original methods used by Archimedes was to use two polygons of with increasing number of sides to approximate a circle (https://itech.fgcu.edu/faculty/clindsey/mhf4404/archimedes/archimedes.html). Since then, proofs have emerged that show that pi is irrational which poses all sorts of interesting ideas, such as that it must consequently be impossible to have a whole number as a diameter and circumference. It also begs the question as to whether a perfect circle is possible in practice. Whilst the topic is interesting, I don`t feel as though there is enough content to write a 5000-word dissertation on. Also, I don`t feel that the topic would allow me to produce a quality extended project piece as the topic allows no scope for evaluation and source analysis.

“The validity of the theory of determinism, especially when considering the seeming randomness of quantum mechanics and radioactive decay.” The theory of determinism states that everything that will ever occur and has occurred is predictable and set-in stone. Essentially, it is an argument that

freewill does not exist. From a purely scientific view, this makes sense as it is basically another way of describing cause and effect. However, with events that appear to be random such as radioactive decay and quantum mechanics, this idea of cause and effect is challenged and hence so is determinism (https://www.independent.co.uk/news/science/free-will-could-all-be-an-illusion-scientists-suggest-after-study-that-shows-choice-could-just-be-a7008181.html). This topic would be extremely interesting to do as it so controversial and certainly requires large amounts of judgement and critical thinking. Whilst the topic satisfies the objectives of the EPQ, I am uncertain as to whether I would be able to produce a 5000-word dissertation on the subject. Although my piece would certainly rely on certain opinions, I could analyse neurological research to form an accurate judgement that would probably allow for an excellent EPQ project.

3 Identify from one of the topics above the project you would like to select and the reasons why.

Out of the aforementioned topics, I think that "The potential future developments of artificial intelligence, considering its current uses" is the most suitable topic for me. This is the topic that I am personally the most interested in and hence the one that I am most likely to be motivated for (which increases the probability of a good project). Unlike some of the other topics, I already have a rudimentary understanding of Artificial Intelligence and its applications which is naturally advantageous. Initially I was going to go for the validity of determinism or the implications of quantum computing on society, but upon reflection I concluded that AI was a far better match for both the task and my personal ambitions as I felt that quantum computing was too limited (especially given that the concepts are very difficult to grasp). It was my view that determinism would have been an interesting topic but one that would ultimately give me a skillset and knowledge that was less suited to my desire to pursue a career in Computer Science.

I feel that the topic will help me acquire an array of skills and in-depth knowledge which may prove vital in the future as I am strongly considering a career in computer science. The topic is somewhat broad and allows me to discuss a wide range of things such as the progression of hardware and applications overtime, current uses for AI (and whether or not they outperform humans), the potential impact of quantum computing on AI, potential future developments of AI (and people`s different views on this) and the ethics of AI. However, the broad nature of the topic means that my research title has to be specific enough to ensure a focused and thorough piece as opposed to one that focuses on lots of elements in little detail. Conversely, I don`t want to make a question that is too broad. Initial ideas for questions include: "To what extent is valid to claim that artificial intelligence will be able to mimic human intelligence in the future when analysing the advancements and uses of artificial intelligence and computer hardware over time?" and "To what extent does artificial intelligence play a role in the socio-economic aspects of our lives?". Although, on balance, I believe that the former has the most merit as I believe that the latter is too restricted in scope to allow me to accumulate the skills and expertise I wish to receive from the EPQ.

Following feedback on my project proposal, I have decided to focus my project on the current uses of artificial intelligence in specific sectors. This is because focusing on potential future developments is too difficult to analyse and doesn`t fulfil the criteria of the EPQ as most of the work available on future developments is speculative. Hence, I decided to focus on analysing the present-day state of Artificial Intelligence. However, this alone would be too broad of a field so I will focus the economic and societal implications of certain AI systems. So, I am essentially just focusing on "the current uses" section of "The potential future developments of artificial intelligence, considering its current uses". As previously noted, the initial topic was extremely broad and on reflection, the focus on certain current uses and their impacts on society will allow for a much more focused piece. This is also much easier to analyse

as all of these systems actually exist and much research has been done on them. The quality of research on the future of AI is low as there is a large focus on speculation.

4. What are the aims and objectives of your selected project? (maximum of 4 objectives)

Aim 1- To thoroughly assess the extent that Artificial Intelligence systems in Medicine contribute to the socio-economic condition of society

Objective 1.1 To clearly set out what Artificial Intelligence systems are.

Objective 1.2 To present the uses of these systems and explain how they contribute to the socio-economic condition of society.

Objective 1.3 To outline the different viewpoints of people in regard to the extent that these systems contribute to (or detract from) society, highlighting where there is general consensus and where controversy exists.

Objective 1.4 To take into account all views to reach a well-informed conclusion as to the impact of medical AI systems on society and whether it`s generally a positive or negative one.

Aim 2 -To thoroughly explore many sources on my research topic

Objective 2.1 To draw from at least 100 sources on the topic of Artificial Intelligence and related areas.

Objective 2.2 To evaluate the reliability of each source in order to ensure that my piece is based on accurate information.

Objective 2.3 To analyse all kinds of resources to ensure a balance of sources, including: books, webpages, academic papers and videos/podcasts.

Aim 3- To create a detailed plan on what I intend to do in my project

Objective 3.1 To create a detailed list of sub-questions which I wish to address in my overall dissertation

Objective 3.2 To research at least 3 time management and project plan resources and reach a conclusion as to which is the most appropriate.

Objective 3.3 To fully break my project down into all of the individual tasks that I will need to perform for my project to be successful.

Objective 3.4 To produce a time management resource that sets specific deadlines for each of the specific tasks in my project to be completed.

Aim 4- To develop the range of skills required to produce a high-quality dissertation

Objective 4.1 To acquire a high level of digital literacy to help my research topics, by making use of Boolean search terms and resources such as Google Scholar.

Objective 4.2 To practice secondary source analysis by researching analysis techniques such as “CAP”.

Objective 4.3 To research the Harvard referencing system and best referencing practices and determine which of these I will use in my project.

5. Is this an individual oproject? (This is an individual project) **Yes** ☒ **No** ☐

For group projects, please state what your individual role is and the roles of the other members of the group.

Not applicable as this is an individual project.

My role is:

The other group members' roles are:

(a)

(b)

(c)

6. What type of project will this be: dissertation/field investigation, artefact, design or performance? Why is this type of project appropriate to your selected topic?

My project will be a dissertation as I feel that this is the most appropriate format. The analysis of Artificial Intelligence and potential future developments in the field is something that requires large amounts of research and writing, something which none of the other options adequately facilitate. To analyse the topic fully, I will need to present a range of factual information as well as multiple viewpoints to come to a well-reasoned conclusion and hence a dissertation is the most appropriate by far. Furthermore, a dissertation also suits me the most as it enables me to acquire the skills I wish to acquire (such as source analysis, writing and referencing) as this will be beneficial when I go on to university.
Following the changing of my topic to focusing on the contribution of AI to society, I still believe that a dissertation is by far the most appropriate format. This is because in order to analyse the contributions of AI to society, one must present a large amount of research on its various uses. Using this research, it is then possible to reach an appropriate conclusion. An artefact would be inappropriate as this would not help at all to evaluate the wide uses of AI in our society.

N.B. Written Extended Project (e.g. dissertation, field investigation) requires a minimum of 5,000 words. Non-written Extended Project (e.g. artefact, design, performance) requires Project Outcome Notes with a minimum of 1,500 words.

7. What skills do you think you will need to develop to complete your Extended Project?

For my project, I will need a myriad of skills.
Research Skills
I will need to develop my ability to find appropriate resources by embracing new technologies such as Boolean operators and advanced search engines such as google scholar and university library search tools (such as the ones provided by the University of Bath). I need to ensure that I use a wide range of relevant sources to ensure a balanced perspective. Critical source selection will also be vital to ensure that only accurate sources are used and that I can understand and explain the shortcomings of certain sources. To do this, I shall research analysis methods, however I shall mainly use the CRAAP method (currency, relevancy, authority, accuracy and purpose). Therefore, good critical thinking is an important skill to ensure wise source selection. It is important that I use good referencing skills (by using the Harvard referencing system) and maintain a detailed bibliography.

Planning and organisation
In order to ensure a successful project, I will need to be very organised. I will create a detailed plan that sets out my essay structure as well as what tasks need to be completed and when by. This time management will be essential to completing the project to the best of my ability whilst not compromising my other A level subjects. I shall also create a reading log to keep track of what sources I am reading as well as some sort of document which keeps all my references in one place. I could use Harvard`s online tool for this.

Problem-solving and decision-making
Throughout my project, I will doubtlessly come across problems which will need to be resolved. For example, it may be that too equally reliable sources make directly contradicting claims. In a scenario like this, I would need to apply logical and critical thinking and analyse each source carefully for citations etc. in order to make an appropriate judgement. Decision-making is also a vital part of any good project and it is important for me to set adequate time aside to make decisions and reflect on previous ones. This will be essential when deciding which elements of my topic to mention as well as what to include in my presentation.

Literacy skills
As I am writing a 5000-word dissertation it is important that I maintain a high standard of literacy to ensure a readable and logical piece. To ensure good spelling, I will need to have a policy of proof reading all of my work. It is also important to utilise drafting to ensure that my project has been iterated on so that I am confident it is of the highest quality possible. Good usage of paragraphs and a wide range of vocabulary will make the piece easier to understand and read, and hence more effective.

Presentation skills
I will need to employ effective presentation skills such as clear oration and script writing in order to create an effective presentation. I will need to develop the ability to synthesise and summarise information for both the presentation and when detailing what sources say. I will also need to become familiar with some form of visual stimulus such as PowerPoint to ensure that my presentation is of high quality. I will need to develop effective communication skills for both my project and presentation.

Reading skills
Due to the complicated nature of artificial intelligence, I need to ensure that I am always reading about the subject to both ensure that I am knowledgeable about the subject and to have a wide range of sources that I can use for my project.

Motivation and time management skills
To ensure that I complete a good project, I will need to be highly motivated so that I am able to carry out the tasks I need on time. This is imperative as I will also have to balance my EPQ with my A-level studies. To ensure motivation, I personally like to create a timetable to ensure that I use available time well.

Technological skills
I will need to use a wide range of new technologies and tools. These include podcasts, utilising library search engines (such as the one our school provides) as well as becoming well versed in tools such as PowerPoint.

8. What resources do you think you will require in completing your Extended Project?

I will need to access to a computer to use a range of digital resources such as videos (such as the ones created by YouTube author 3blue1brown on neural networks: https://www.youtube.com/playlist?list=PLZHQObOWTQDNU6R1_67000Dx_ZCJB-3pi and TED talks), podcasts, news articles and search engines.
I will need access to various academic journals on artificial intelligence and general computer science such as the nature journal (I have already identified an entry on October the 23rd that would be useful).
I will need to access certain books on the subject, many of which can be found for free online or in my school library. One book I have found that seems appropriate is: "Peter Norvig, Artificial Intelligence: A Modern Approach".
I will need access to resources found in my school library.
Government statistics on things such as the number of jobs being replaced by automation would also be useful though not essential.
Setting up an interview with a specialist would also be useful and I could achieve this by emailing potential people to interview, such as authors of academic pieces.
Fortunately, I already have access to most of these resources through my school library as well as through free digital resources (although it may be necessary to purchase certain books). Some of the other resources may be more difficult to gain access to (such as a specialist), however these are not required to make an effective piece, although they may be helpful depending on the specific resource.

9. How do you think your Extended Project will help you to meet your aspirations (e.g. further study, employment)?

My extended project will help me in numerous ways. I intend to apply to University next year and I believe that a strong project will increase my chances of a successful application. The skills I will acquire will prove imperative in university as essay and dissertation writing are something that occurs in every course. The skills of independence, research, source analysis and essay writing are all important skills both for university and in the wider world of employment.
My ambition is to one day become a computer scientist and therefore this project will help me in gaining an understanding in one of the biggest aspects of high-level computer science. It is highly likely that I may one day end up writing an artificial intelligence application and hence my knowledge on the subject would be massively helpful. However, the skills of the EPQ aren`t just helpful for further education and employment as skills such as digitally literacy, good thinking, essay writing and delivering presentations are vital in countless areas of life.

10. Please include any other additional information relevant to your project development.
(Please attach any additional documents to support your statement e.g. mind maps)

Initially, I brainstormed potential topics and their merits and shortcomings:
Potential Extended Project Qualification Research Topics
Computer Science
Artificial Intelligence:

Will Artificial Intelligence ever be able to mimic human intelligence? (broad)

Artificial Intelligence (AI) is quickly growing field that already sees a wide range of applications. It has already surpassed humans in many individual fields such as data analysis. However, in many fields it tends to have a higher error rate and thus is often accompanied by a human as AI`s tend to make mistakes that humans would never make. However, superiority in certain fields such as chess begs the question as to whether an artificial intelligence system could ever surpass a human. Whilst unlikely at the moment, one must consider that that a brain is merely a highly advanced computer with billions of years of evolution to perfect itself. Therefore, it is wholly reasonable to assume that mimicking this programmatically is wholly possible. However, what resources and advancements would be necessary for this to be possible? With Google having recently created a functioning quantum computer containing 53 qubits, one could argue that the processing power needed to perform such a function is getting closer. For this topic, I could also explore existing fields that AI may soon replace. I could also analyse the limitations of AI as it really boils down to mass memorisation of data and attempting to extract a pattern from it. And as technology gets more fine-tuned, the ability to create more powerful and concise hardware dwindles as perfection draws closer, potential requiring large innovation (e.g. quantum computing). https://medium.com/datadriveninvestor/evolution-of-ai-past-present-future-6f995d5f964a

Potential subtopics if question is too broad:

What are the limitations and advantages of neural networks?

Neural networks consist of a series of input nodes with output and input nodes. It is essentially a highly advanced calculation the aims to alter the “strength” of biases and connections between each node to find a local minimum at which the desired output is closest to the actual output through training data. One could argue that the computer is actually learning through this process but merely memorising as much data as possible (e.g. number recognition neural networks have a high accuracy rate with just numbers but will also appear to be “certain” that a letter is a number).

What are the current and potential future applications of Artificial Intelligence?

Current application includes stock market analysis, conversation simulation, attempts to detect spam etc. Future uses could include self-driving vehicles, diagnosis of patients and possibly virtual secretaries.

Physics
Quantum Mechanics:

What real world applications does quantum mechanics have?

The ground-breaking field of quantum mechanics seems to be incompatible with classical physics and suggests that there is an underlying field of physics which is yet to have been fully discovered. For example, quantum superposition essentially shows that a particle can be in two different places at once and in a combination of different states until it is observed, forcing it chose a position. Due to this, one can`t actually predict where an electron will be, merely the probability of it being in a particular location. Quantum mechanics is full of these bizarre unexplained phenomena and these suggest that true randomness does in fact exist. Whilst scientists are nowhere near fully understanding quantum mechanics, the idea of inherent randomness is a troubling one as all scientific principles are based on

the notion of cause and effect- an idea which many argue is incompatible with true free will. Beside the philosophical application, there is naturally a myriad of scientific developments that stem from this field. One exciting development is that of quantum computing which uses qubits. As opposed to a typical two state device that can be 1 or 0, a qubit can be 1,0 or 1 and 0 at the same time. Recently, a team at Alphabet created a quantum computer with 53 qubits which is believed to be 1080 times more powerful than the current most powerful supercomputer. Researchers have also managed to transmit information instantaneously into outer space suing quantum entanglement, branding it “teleportation”. Clearly, there are many real-world applications.

Potential subtopics if question is too broad:

What is quantum computing and how can it be used?

The use of qubits hypothetically allows for exponentially more powerful hardware which would have massive application in the development of artificial intelligence and simulations which would drastically increase the speed of finding cures for disease (e.g. cancer). However, there is still a long way to go yet.

What is quantum mechanics?

(see above)

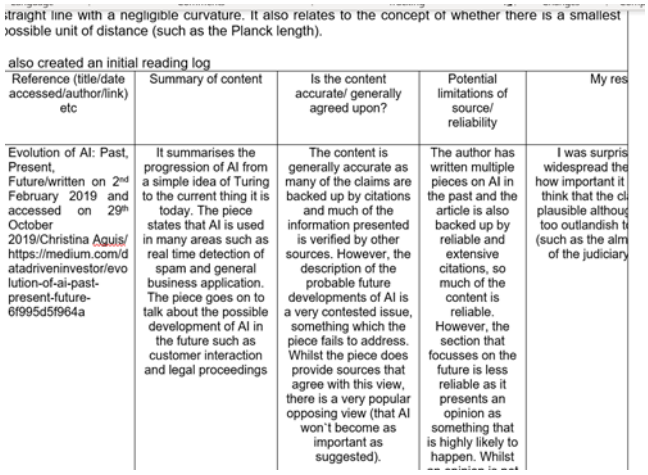
Mathematics

Pi:

How was pi found and is it irrational?

Pi is the ratio between the circumference and diameter of a circle. Archimedes took a polygon both inside and outside the circle and made it with an ever-increasing number of sides to find a rough estimate of pi. Pi = circumference/ diameter, yet it is believed to be irrational. This would suggest that it is impossible for a circle to have a circumference and diameter which is a whole number. It also begs the question as to whether a perfect circle even can exist as, on a molecular level, a circle is really just a collection of dots that are so close together that they form tiny straight lines. For example, it is impossible for a computer to draw a circle as it is just a collection of straight lines. This can be brought back to concepts such as differentiation which essentially treat a curve at a certain point as a straight line with a negligible curvature. It also relates to the concept of whether there is a smallest possible unit of distance (such as the Planck length).

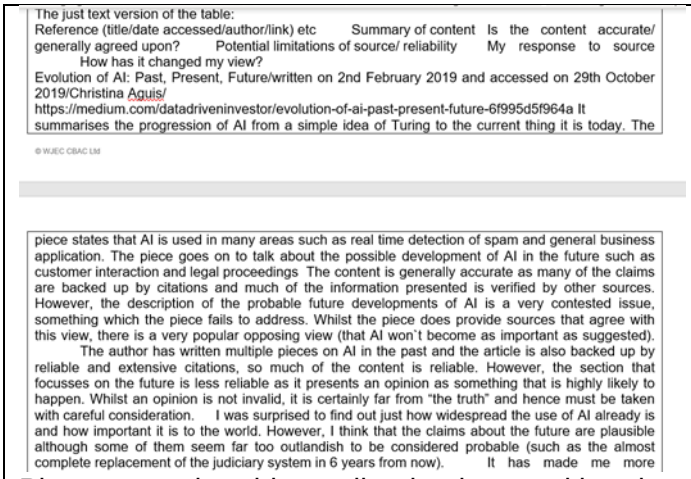
I also created an initial reading log, although initially it was in a format that obscured part of the table from view. It looked like this:


straight line with a negligible curvature. It also relates to the concept of whether there is a smallest possible unit of distance (such as the Planck length).

also created an initial reading log

Reference (title/date accessed/author/link) etc	Summary of content	Is the content accurate/ generally agreed upon?	Potential limitations of source/ reliability	My res
Evolution of AI: Past, Present, Future/written on 2nd February 2019 and accessed on 29th October 2019/Christina Aguis/ https://medium.com/datadriveninvestor/evolution-of-ai-past-present-future-6f995d5f964a	It summarises the progression of AI from a simple idea of Turing to the current thing it is today. The piece states that AI is used in many areas such as real time detection of spam and general business application. The piece goes on to talk about the possible development of AI in the future such as customer interaction and legal proceedings	The content is generally accurate as many of the claims are backed up by citations and much of the information presented is verified by other sources. However, the description of the probable future developments of AI is a very contested issue, something which the piece fails to address. Whilst the piece does provide sources that agree with this view, there is a very popular opposing view (that AI won't become as important as suggested).	The author has written multiple pieces on AI in the past and the article is also backed up by reliable and extensive citations, so much of the content is reliable. However, the section that focusses on the future is less reliable as it presents an opinion as something that is highly likely to happen. Whilst	I was surpris widespread the how important it think that the cl plausible althou too outlandish t (such as the alm of the judiciary

I was forced to include a copy of the text in each own as well, which made the piece very messy to look at:



The just text version of the table:
Reference (title/date accessed/author/link) etc Summary of content Is the content accurate/ generally agreed upon? Potential limitations of source/ reliability My response to source How has it changed my view?
Evolution of AI: Past, Present, Future/written on 2nd February 2019 and accessed on 29th October 2019/Christina Aguis/
https://medium.com/datadriveninvestor/evolution-of-ai-past-present-future-6f995d5f964a It summarises the progression of AI from a simple idea of Turing to the current thing it is today. The piece states that AI is used in many areas such as real time detection of spam and general business application. The piece goes on to talk about the possible development of AI in the future such as customer interaction and legal proceedings The content is generally accurate as many of the claims are backed up by citations and much of the information presented is verified by other sources. However, the description of the probable future developments of AI is a very contested issue, something which the piece fails to address. Whilst the piece does provide sources that agree with this view, there is a very popular opposing view (that AI won't become as important as suggested).
The author has written multiple pieces on AI in the past and the article is also backed up by reliable and extensive citations, so much of the content is reliable. However, the section that focusses on the future is less reliable as it presents an opinion as something that is highly likely to happen. Whilst an opinion is not invalid, it is certainly far from "the truth" and hence must be taken with careful consideration. I was surprised to find out just how widespread the use of AI already is and how important it is to the world. However, I think that the claims about the future are plausible although some of them seem far too outlandish to be considered probable (such as the almost complete replacement of the judiciary system in 6 years from now). It has made me more

Please note that this reading log is a working document and is being updated constantly. I included this as a way to keep track of all the sources I was reading and wish to use in my project. I ensured that I followed due process with each source to ensure that all sources are accurate and appropriate for use in my project.

Reference (title/date accessed/author/link) etc	Summary of content	Is the content accurate/ generally agreed upon?	Potential limitations of source/ reliability	My response to source	How has it changed my view?
Evolution of AI: Past, Present, Future/written on 2nd February 2019 and accessed on 29th October 2019/Christina Aguis/ https://medium.com/datadriveninvestor/evolution-of-ai-past-present-future-6f995d5f964a	It summarises the progression of AI from a simple idea from Turing to the current thing it is today. The piece states that AI is used in many areas such as real time detection of spam and general business application. The piece goes on to talk about the possible development of AI in the	The content is generally accurate as many of the claims are backed up by citations and much of the information presented is verified by other sources. However, the description of the probable future developments of AI is a very contested issue, something which the piece fails to address. Whilst the piece does provide sources that agree with this view, there is a very popular opposing view (that AI	The author has written multiple pieces on AI in the past and the article is also backed up by reliable and extensive citations, so much of the content is reliable. However, the section that focusses on the future is less reliable as it presents an	I was surprised to find out just how widespread the use of AI already is and how important it is to the world. However, I think that the claims about the future are plausible although some of them seem far too outlandish to be considered probable (such as the almost complete replacement of the judiciary system 6 years from now).	It has made me more aware of the possible developments of AI and how widespread the technology already is, although my general belief is still similar to what it was before reading this article.

	future such as customer interaction and legal proceedings	won`t become as important as suggested).	opinion as something that is highly likely to happen. Whilst an opinion is not invalid, it is certainly far from "the truth" and hence must be taken with careful consideration.			
Quantum Physics Introduction for Beginners/ accessed on 29th October 2019 https://quantumphysicsmadesimple.com/introduction-for-beginners/	The piece details the basics of quantum mechanics. It describes the two slit experiment which proves that electrons and photons act as waves on a microscopic scale. It states that they are believed to have dual wave and particle properties. This wave like ability is at a clash with classic physics and the location at which the light will	The content is highly accurate as I cross referenced this information with other sources which all explained the same thing.	The fact that the author of the piece is not clearly visible is somewhat strange. The focus on simplifying the content may lead to summaries that are too simplistic. However, the clearly educational focus along with the numerous citations and accurate content would definitely suggest	I found all the information presented highly informative.	My view hasn`t changed.	

	appear on the wall appears to be random as it can only be predicted statistically. The piece makes brief reference of quantum entanglement, which is when two particles seem to exhibit the same properties as each other, despite being miles apart.		a reliable source.			
Written by New Indian Express? Published on the 29th of October 2019/ accessed on the 29th October 2019/Google's striking Quantum Computer feat; is the world ready for what comes next? https://www.newindianexpress.com/business/2019/oct/29/googles-striking-quantum-computer-feat-is-the-world-ready-for-what-comes-next-2054338.html	The piece describes how a team of researchers have made a working quantum computer that is at least 1080 times more powerful than the current most powerful computer in the world.	The content appears to be fairly accurate as other news outlets have reported similar details.	The source includes no citations and whilst seemingly accurate is of reduced use to me as it focuses less on the science behind the computer.	I was shocked by the fact that quantum computing allows for an exponentially more powerful computer and could threaten modern banking security.	I am surprised as to how much quantum computing has already developed.	
Calculating Pi (π)? Accessed on October 29th, 2019/ https://www.mathscareers.org.uk/article/calculating-pi/	The piece describes Archimedes initial attempts to calculate pi by drawing polygons	The contents appear to be accurate as I have verified the content with other sources. The website would suggest an	No citations are included, and the author is unknown, but the	I was left wondering why pi is irrational (if it is) as it is equal to circumference/ diameter. This would suggest that it is impossible to	My view of pi is still much the same.	

	outside and inside a circle in an attempt to approximate pi, the ratio between the diameter and circumference of a circle. It also talks about various formulas that are utilised to calculate the value and how pi appears to be never ending.	educational focus. The site is maintained by the Institute of Mathematics and its Applications, which would suggest a focus on accuracy. All of the content is agreed upon generally.	content is clearly accurate and reflective of the whole topic, so I would still say that it's a decent source.	have a circle with both a whole number as the circumference and radius.		
Free Will/ accessed on 21.11.2019/ https://books.google.co.uk/books?hl=en&lr=&id=DUycAQAAQBAJ&oi=fnd&pg=PP2&dq=freewill&ots=qFRs4mKxnC&sig=zt1Bb6WyLPcwUbv70ANtqtCdDwI#v=onepage&q=freewill&f=false Gary Watson	The piece is a collection of various arguments on the subject of determinism	Whilst the piece presents different viewpoints, the inherently philosophical nature of the paper does lead to contradiction, however all of the pieces are well argued and reasoned	There are few potential shortcomings as each piece is well cited and argued rationally. Although, one could argue that the subjective nature of the pieces is a potential flaw.	I read the introduction by Gary Watson and I was rather intrigued by the notion that if determinism is true, holding somebody responsible and hence legal repercussions may be inappropriate.	It has certainly broadened my perspective on arguments for and against freewill	
https://www.youtube.com/playlist?list=PLZHQObOWTQDNU6R1_67000Dx_ZCJB-3pi (accessed on 24th November 2019)/3Blue1Brown/Neural Network Playlist	The piece details how neural networks function and learn by describing it as a set of nodes	The piece seems to be reliable as its sole purpose appears to be to educate the audience. All of the processes it describes are	Whilst the piece appears to be highly accurate and informative, the fact that	I was surprised to find that the seemingly magical deep learning is a merely just a collection of complicated sums and attempts to	The piece has led me to appreciate just how advanced ai can be but also its limitations as it struggles to deal with scenarios it hasn`t prepared for. For example, a network that	

	and biases that need to be minimised or maximised in order to for them to produce a desired output.	verifiably true such as the use of the sigmoid function to streamline values.	it`s a YouTube video might suggest that the purpose is to make money and entertain the audience, so it is possible that corners have been cut. However, given the sheer accuracy and educational focus of the channel, I think it is very safe to say that the piece is reliable.	find a local minimum.	recognises handwritten digits will also say with a high degree of certainty that nonsensical images contain something like the number 5 (when in fact they don`t).	
https://www.bbc.co.uk/news/science-environment-37408013 accessed on 24th November 2019/ Teleportation step toward quantum internet/ Paul Rincon	The piece details how a team of researchers were able to transmit information instantly and wirelessly over 8km using quantum entanglement.	The piece is a news article by the BBC, a reputable organisation who are reliable. The piece summarises a specific case as well as mentioning other examples of quantum teleportation and as such is highly reliable as it is summarising the results of reputable experiments.	The piece is inhibited by the fact that all its information stems from the people who performed the experiment. Whilst they will want to produce an accurate experiment, they are also more	I was surprised to discover that instantaneous transmission of information was possible, and I was also shocked to discover that this may potentially be used in a quantum internet one day.	I have become more impressed with the potential applications of quantum mechanics.	

			likely to give an exaggerated impression of the potential uses of this technology.			
https://www.bloomberg.com/opinion/articles/2019-11-15/google-s-quantum-computing-leap-is-small-step-for-computers 24th November 2019/ Quantum Leap for Computing Is a Small Step for Computers/ Ariel Procaccia	The piece details Google`s claim of quantum supremacy after they created a working quantum computer. However, the piece also points out the flaws in the computer and states that the technology still has a long way to go.	The content seems to be fairly accurate as presents a similar story to other publications. The article has some citations and acknowledges that Google's claim of processing speed has been credibly disputed.	The source does however use a lot of opinionated language and seems generally sceptical on the achievement. Despite the somewhat biased tone, it does make some valid claims and draws parallels with AI in that it is good at specialist tasks but less so at more generalised ones.	It shocked me to hear just how much faster a quantum computer is than a normal one, however it also presented a more down to earth impression of the achievement than other places have, reminding me that the technology is still nowhere near ready.	This piece has helped me understand both the potential of quantum computing and also the many things that need to be overcome in order for it to become a viable technology.	
https://www.extremetech.com/extreme/284306-how-quantum-computing-works 24 th November 2019/ How Does Quantum Computing	Then article talks about the basics of how quantum computing works by explaining	The piece seems to be well informed and all the information presented is generally agreed upon in the community. It provides	The article is on a website titled extreme tech which doesn't full inspire	The source has helped understand some of the more complicated aspects of how quantum computers function as well as they	After reading the piece, I have become more aware of the potential quantum computing has but also that it is extremely difficult to create an effective one.	

Work? / Dave Cardinal	concepts such as quantum superposition and entanglement. The piece explains how this could theoretically result in an extremely powerful computer.	multiple resources for those wishing to enhance their understanding of the subject, hence suggesting that the piece is reliable.	reliability as it seems that users may publish articles if they wish.	threat the pose to cybersecurity.		
https://www.independent.co.uk/news/science/free-will-could-all-be-an-illusion-scientists-suggest-after-study-that-shows-choice-could-just-be-a7008181.html 24th November 2019/ Free will could all be an illusion, scientists suggest after study shows choice may just be brain tricking itself/Andrew Griffin	The piece details psychological experiments where participants seemed to claim that they had made decisions which were impossible for them to have actually made themselves. This suggests that the brain retrospectively justifies actions that had already been made, giving an illusion of freewill.	The piece does correctly summarise multiple research papers, even though it is a very shallow summary that fails to offer alternative explanations for the results. Furthermore, there is still much contention in the community as to whether these experiments prove an absence of freewill in certain areas.	Each research piece is only talked about very briefly and in doing so it does summarise the general content but simplifies the conclusions and experiments too much. The article lacks citations although it is from a respected publication	Despite the shortcomings of the source, I am surprised to learn that the brain seems to subconsciously make a decision and gives us the illusion of choice by retrospectively justifying it.	My view has shifted more towards the concept of determinism as it appears that at least in specific instances, our brain gives us the illusion of freewill.	
Archimede`s Approximation of Pi/ the author is unknown https://itech.fgcu.edu/faculty/clindsey/mhf4404/archimedes/archimedes.html November 24 th 2019	The piece details how Archimedes originally arrived at his approximation of pi.	The piece is generally agreed on and is essentially just a summary of Archimedes` steps which is verifiably correct. It includes	The piece is well cited and sets out its sources as well as being accurate. Howeve	I find it fascinating how Archimedes used polygon similar to a circle to create a very accurate estimate of pi.	It has given me a more thorough view on how pi was found.	

		numerous citations, and it states that it is using Heath`s translation.	r, the piece is very old, the website (despite being a .edu) is very basic and I am unable to find the author of the article. One of the links also no longer works.			
https://www.bbc.co.uk/news/health-50857759 accessed on 3rd January 2020	This piece summarises the finding of a study that uses AI to analyse breast scans to determine whether the person has cancer. Over just under 29,000 participants the AI system had 1.2% fewer false positives and a 2.7% reduction in false positives. The study goes on to conclude that AI could be used to increase efficiency as currently, two	The piece is a reputable study with a very large sample size of data. However, the research is done by Google Health. Google is a company that heavily invests in the field of artificial intelligence, potentially making it less reliable. However, the study is really well done, and the findings are not contested.	As mentioned, the piece is done by a research team at Google who invest massively in the field. Despite this, the study is done very professionally and hence I think it`s safe to say the study is reliable and trustworthy.	I was genuinely shocked to find out how effective the AI already is. The fact that it clearly outperformed the expert is really impressive and shows great promise for the future. However, it`s still worth considering that the AI would probably struggle with rare cases of breast cancer as it may not have been trained to deal with it.	I am now much more convinced of the capabilities of image recognition technology and the uses of AI in the field.	

	radiologists are required to analyse one scan. The piece suggests that the second specialist could be replaced by the AI.				

Here is a copy of my self-assessment form I filled in upon completion of my first draft:

Self-Assessment Grid

AC3.1 Conduct research using a range of resources, select and apply information and data relevant to the planned outcome.

			
I have conducted research using a **wide range** of relevant resources. (academic journals and papers, books, websites etc)	x		
I have included **complex material.**	x		
I have consistently **applied** information/data to the planned outcome.	x		
All resources are acknowledged and **referenced** using a recognised form. (Harvard Referencing)	x		

Reflection- based on the above self-assessment consider how you will improve your dissertation

I feel I have used a wide range of reliable and credible resources, even if most resources are academic papers or web articles. However, I do also include newspaper articles, books, podcasts, and videos although these types of sources are used less than journal entries.
Create a SMART target based on the above reflection: Continue to ensure a diversity of sources by using more resources such as videos.

AC4.1 Interpret and analyse selected information and data and apply to support the outcome.

			
I have explored and confirmed the **validity and bias** of resources.	x		
I have demonstrated the ability to **synthesise complex information/data.**	x		
I have a Comprehensive understanding of links and fully explored and established **sophisticated connections**	x		
I have **interpreted and analysed** relevant information/data to inform a **cohesive outcome and conclusion**.	x		
I have **not simply listed and described** the sources I have read, but have **critically evaluated the links** between texts to formulate a **critical argument**	x		

Reflection- based on the above self-assessment consider how you will improve your dissertation

I have interpreted and analysed a wide range of resources including their reliability and links between them. I feel that I initially listed sources as opposed to analysing them in great detail, but I feel I have addressed and rectified this.
Create a SMART target based on the above reflection: Continue to analyse sources critically and ensure information is synthesised, debated and linked to the theme of the dissertation well.

AC5.1 Select and use a range of skills, including new technologies, where appropriate, to reach critical decisions that contribute to the process and outcome.

			
I have critically selected and **effectively** applied **a range of skills with precision** relevant to the specific project.	x		
I have **Embraced** new technologies, using them **creatively**, where appropriate.	x		

Reflection- based on the above self-assessment consider how you will improve your dissertation

I have used a range of skills in this essay such as synthesis and critical analysis. I have certainly embraced new technologies through use of a wide range of mediums, use of technology such as Google Scholar (and its advanced search features) and through the coding of my own self-learning artificial intelligence system to gain a deeper understanding of the topic.
Create a SMART target based on the above reflection: When re-drafting my project, I will focus on continuing to hone and apply critical skills such as analysis of conflicting sources to form valid conclusions.

AC6.1 Produces a planned outcome and completes the project in its entirety.

			
I have produced a cohesive project demonstrating knowledge and understanding of the topic authoritatively.	x		

Reflection- based on the above self-assessment consider how you will improve your dissertation

I have used a wide range of resources to comprehensively answer the question of the dissertation and have thoroughly assessed all areas of it. The project is also cohesive as it is structured in a way that covers all relevant aspects of the topic and then reaches an informed conclusion.
Create a SMART target based on the above reflection: I will continue to ensure that my concluding arguments are cohesive and maintain a clear line of thought.

Here is a copy of feedback from my first EPQ draft:
Very good overall - it is a great question to discuss and you do it well.

There's the odd thing I noticed - such as digitally literate? - bottom of page 10

I think it's bordering on being too long, see below from WJEC EPQ student guide.

Learners will not be penalised for going over the 5000 words. If, however, learners went way beyond the 5000 words, e.g. 8000-10000 words), WJEC would then question whether learners succeeded to keep your project focused enough

With this in mind as yours is over 8000, could some of the AF detail be put into an appendix? So it's still there but not in the main body of the dissertation? Or any other part you think could be trimmed and/or the detail transferred to an appendix

You must use Harvard referencing - you don't need numbers at all - see next 2 pages for how to do referencing in text and quotes.

The last two pages tell you how to create a list of references

How to reference correctly

References within the text

When the Harvard system is used, acknowledgement of the work of others appears within the text; it includes paraphrasing as well as making direct quotations. (N.B. Footnotes do not need to be used with this system; however, your tutor may allow you to use them to expand or qualify points in the text.) You need to note the author's surname, followed by the year of publication and, for a direct quotation, the page number e.g. (Bloggs 2006: 12).

Where **you** are citing from more than one work published by an author in one year you add a lower case letter after the year e.g. (Bloggs 2006a).

Where there are **two or three authors**, give the surnames of authors e.g. (Bloggs and Smith 2006) or (Bloggs, Smith and Jones 2007).

Where there are **four or more authors,** give the surname of the first followed by *et al* e.g. (Bloggs *et al* 2006). The full reference details for all authors *mus*t be included in the final reference list.

There are several ways in which these references can be made; there are some examples below. (The full details of sources are given in the list of references at the end; see the next section.)

Quotation

If you take a passage, a sentence, a phrase, or even a distinctive word from a book, article, or other source you ***must*** put the borrowed material in single quotation marks (with double quotation marks for a quote within a quote). Quotations and their introductory clauses need to be grammatically complete. If something is left out of the original quotation then three dots should be used to show the omission. If you add words, these should be in square brackets.

e.g.
He lists twenty-four names of people who had 'felt hitherto strange and unfamiliar desire to have images formed by light spontaneously fix themselves' from as early as 1782 (Batchen 1990: 9).

e.g.
It is hard to disagree with Slee's statement that 'schooling has always produced exclusion' (2001: 113).

e.g.
Teaching at this level was seen 'as a student-centred activity in which students are not only responsible for their own learning process but also are in control of the content of their learning' (Samuelowicz and Bain 1992: 98).

A longer quotation (**more than two lines**) should be indented on both left and right and single spaced in a separate paragraph.

e.g.
They also comment on the functions of literacy:

Participating in literacy at any level … can improve quality of life, increase social interactions and relatedness, and improve communication in additional functional contexts. (Kaderavek and Rabidoux 2004: 242)

How to Paraphrase

If you paraphrase or summarise information or ideas from a book, article, or other source you must take great care to put the information into your own words, and you must, again, clearly indicate the source from which the information came. If the reference is placed at the end of a sentence it is inserted before the full-stop.

e.g.
Biographies of Rossetti tend to differentiate the successive stages of his career by associating each of them with a particular woman in his life (Prettejohn 1997).

e.g.
Evans and Saint-Aubin (2005) show how pictures totally capture the attention of very young children being read to by their parents.

e.g.
In a further article (Johnson, 2004a) it is argued that...

e.g.
In this article (Nicholls *et al* 2000) the view is taken that...

e.g.
Harris (1991) showed in his research that...

e.g.
This finding has been confirmed by other researchers in the United States (Smart 2001; Billings and Brown 2004).

Creating a list of references

The purpose of a reference list is to enable all the sources you cite to be easily retrieved by others. Every submission on this programme must include a reference list. A reference list and a bibliography are not interchangeable.

1. Introduction

All written work should include a list of references at the end detailing, in alphabetical order by author, all the sources you used to research the topic.

When there are two authors, cite them both. For three or more authors, cite the first author followed by *et al (*and others – from the Latin *et alii, et aliae).*

The following guide combines the conventions used in the Harvard System and the style recommended by the Institute of Education. Remember the principles and order:

- Creator/author
- Year of publication
- Title of information
  Tracing information

2. Book

1. Surname and initials of author(s) (**if editor/editors,** put ed/eds in brackets after the name)
2. Year of publication (in brackets)
3. Title of book (in italics)
4. Edition (omit if first edition)
5. Place of Publication
6. Publisher

If you have accessed a book or report on-line, you should reference it as a book but add further details to assist in tracing.

e.g.

Clark, A. and Moss, P. (2001) *Listening to young children: the Mosaic Approach* London: National Children's Bureau

Cohen, L. *et al* (2007) *Research methods in education* 6th edn London: Routledge

Department for Education and Skills (2006) *The five year strategy for children and learners: maintaining the excellent progress* London: DFES [online]. http://www.dfes.gov.uk/publications/5yearstrategyprogress/index.shtml [accessed12 January 2007]

3. ***Article/chapter in edited book***

1. Surname and initials of author(s)
2. Year of publication (in brackets)
3. Title of article
4. *in* then surname and initials of editor/editors of book, followed by (ed)/(eds)

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5. Title of book (in italics)
6. Place of publication
7. Publisher

e.g.

Carpenter, B. and Morris, D. (2001) English *in* Carpenter, B., Ashdown, R. and Bovair, K. (eds) *Enabling access: effective teaching and learning for pupils with learning difficulties* London: David Fulton

4. ***Article in journal or newspaper***

1. Surname and initials of author(s)
2. Yes of publication (in brackets)
3. Title of article
4. Title of journal/newspaper (in italics)
5. Volume number
6. Part number (in brackets)
7. Page number(s)

e.g.

Hall, K. (2001) An analysis of primary literary policy in England using Barthes' notion of 'readerly' and 'writerly' texts *Journal of Early Childhood Literacy* 1(2), 153-165

Sheehy, K. (2005) Morphing images: a potential tool for teaching word recognition to children with severe learning difficulties *British Journal of Educational Technology* 36(2), 293-301

Revell, P. (2005) Each to their own *Guardian* May 31 2005, 10

Here is a copy of the title approval:

STAGE 2 – DECIDING ON A PROJECT TITLE

Proposed Project Title: ~~To what~~ Will Artificial Intelligence ever be able to mimic human intelligence?

Project format/type: Dissertation

Comments by supervisor:

Signed off by supervisor: T. Hendy **Date:** 9/1/20

Amended Working Project Title: *(if applicable)* To what extent do the use of artificial intelligence systems in data analysis and medicine contribute to socio-economic condition of society?

STAGE 3 - APPROVAL BY CENTRE PROJECT CO-ORDINATOR (if different to supervisor)

N.B. The check-list below will help in the approval of project titles.

1. Does the project title reflect the project outcome and is it of sufficient challenge? ☑
2. Does the chosen topic provide scope to fulfil the requirements of the Extended Project? ☑
3. Have the necessary checks been made with other subject teachers to ensure there is no risk of dual accreditation? ☑
4. Does the project allow the learner to provide evidence of the four assessment objectives? ☑
5. Is the selected project type/format appropriate to the proposed project title? ☑
6. For group projects, is the learner's individual role stated in the project title? ☐

Comments by Centre Co-ordinator:

Approved: ☑ **Conditional Approval:** ☐ **Not approved:** ☐

Approved Working Project Title:

Signature: **Date:** 9.1.20

Approved Working Project Title (if re-submitted):

Approved by: **Date:**

NB: Approved project titles may be refined during the course of the project.

STAGE 2 – DECIDING ON A PROJECT TITLE

Proposed Project Title: Will artificial intelligence ever be able to mimic human intelligence?

Project format/type: Dissertation

Comments by supervisor:

Signed off by supervisor: **Date:**

Amended Working Project Title: *(if applicable)* To what extent do the use of artificial intelligence systems in data analysis and medicine contribute to the socio-economic condition of society?

STAGE 3 - APPROVAL BY CENTRE PROJECT CO-ORDINATOR

N.B. The check list below will help in the approval of project titles.

Does the project title reflect the project outcome and is it of sufficient challenge?	☐
Does the chosen topic provide scope to fulfil the requirements of the Extended Project?	☐
Does the project allow the learner to provide evidence of the four assessment objectives?	☐
Is the selected project type/format appropriate to the proposed project title?	☐
For group projects, is the learner's individual role stated in the project title?	☐

Comments by Centre Co-ordinator:

Approved: ☐ **Conditional Approval:** ☐ **Not approved:** ☐

Approved Working Project Title:

Signature: **Date:**

Approved Working Project Title (if re-submitted):

Approved by: _____ **Date:** _____

NB: Approved project titles may be refined during the course of the project.

EPF 2a	EXTENDED PROJECT PLAN	wjec cbac

Note: All learners are required to produce an Initial Extended Project Plan once the Project Proposal and Title are approved. This is the forward planning tool that will help define the development of the project. Learners are free to devise their own project plan as long as the following are included:

Key tasks and activities
Targets and milestones
Dates and deadlines

The Initial Project Plan could be in any format, e.g. Gantt chart

INITIAL PROJECT PLAN

In order to create an effective project plan, it is important that I utilise an appropriate format. Hence, I have researched multiple planning tools.
The first method that I considered was simply making a table that lays out all the information in chronological order. This is advantageous as it is easy to make, easy to fit detailed information in and also easy to see what targets need completing next. However, it is limited by the fact that a table in a word document can often become squashed when fitting in multiple columns and hence doesn`t look very good. The table format is visually inferior to other methods and hence makes it harder to understand what needs to be done and by when. Tables are also not very good at showing tasks that need to be performed simultaneously. Despite all this, tables are still a viable option for me.
A Gantt chart is what one can imagine as a table with dates going across the top and events going down the side. For each event one “colours in” the time period across which the event should occur. For example:

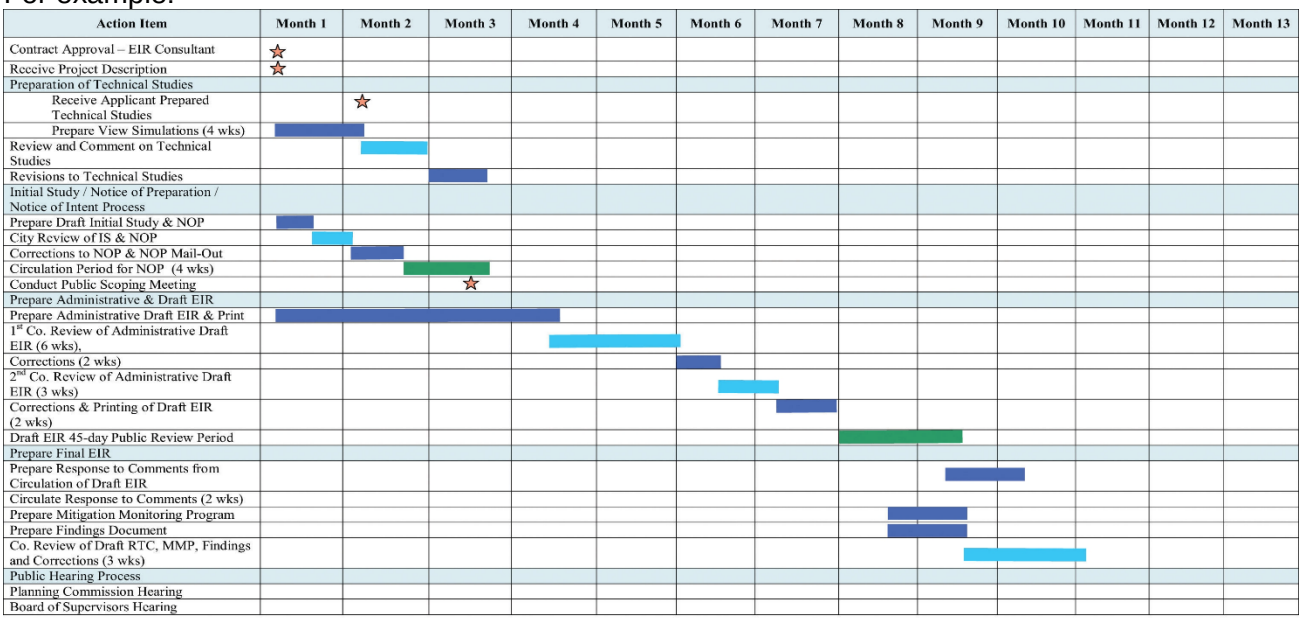

Image source (https://2012books.lardbucket.org/books/geographic-information-system-basics/s14-gis-project-management.html)
The Gantt method is useful due to its visual clarity which makes it very easy to understand what

needs to be done and when by. This format also accounts for overlapping events; however, it is limited by the fact that the actions tend to be described in less detail.

I also researched the Pert chart which is essentially a complex flowchart. All the key milestones are mapped out and connected together by nodes, highlighting both the chronological order of tasks and whether the ability to start one tasks hinges on the completion of another. This is frequently used in large projects as it helps provide a clear picture of complex tasks and gives a great understanding of what needs to be done to complete a project. However, Pert charts are very difficult to produce and interpret effectively. Hence, I feel that this format is inappropriate as the whole point of my plan is to easily understand what I need to do and when by to evaluate my progress. An example of a pert chart is:

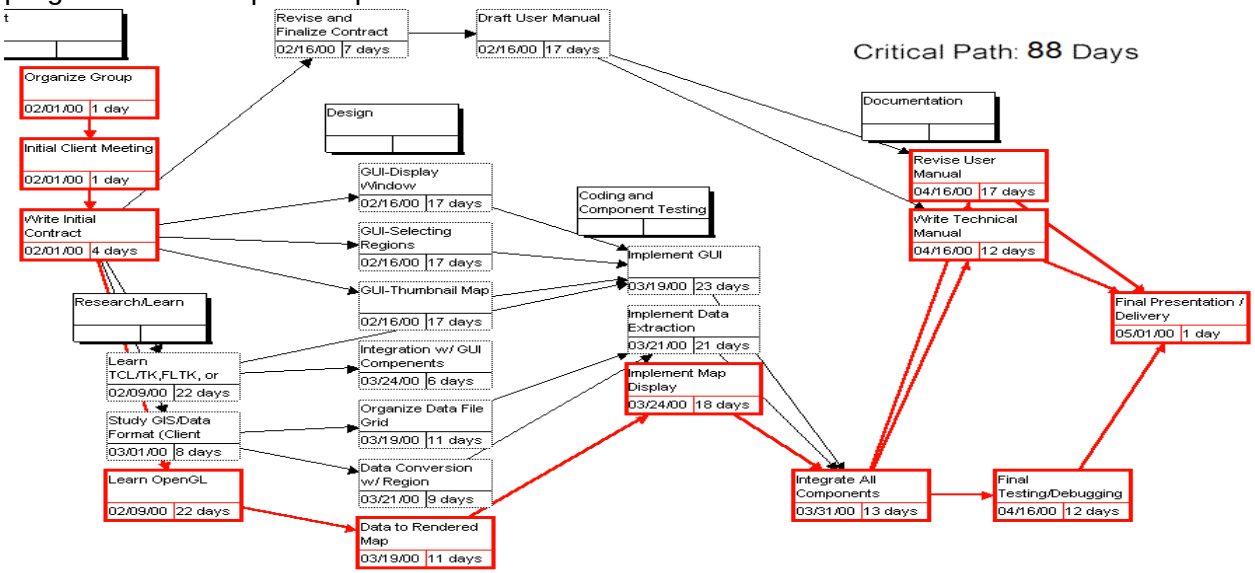

Image source (http://www.cs.unc.edu/~stotts/145/homes/map/images/pert.gif)

Initially I decided upon using a Gantt chart to plan my project however, I felt that the lack of detail on each heading was a major shortcoming. Hence, I have decided to combine the Gantt chart with a table. By doing this, I will be able get a clear sense of what needs doing by when as well as a detailed description of each heading. My table will essentially act as a clarification of each Gannt chart heading. I have decided to use fortnightly intervals to provide flexibility in my targets to allow for adequate study time for my a-levels when the need arises. I will use the SMART targets model to make my targets. Hence, I get the best of both worlds with the readability and clear sense of time management along with the detail and bullet points of what needs to be done.

Here is the table of my current plan:

Start Date and Deadline	Targets and Milestones	Key Tasks and Activities
7th Oct – 21st Oct (2019)	Brainstorm and research potential research topics	Choose three possible broad topic areas. For each topic area, think of 3 specific elements of each topic for example, the broad area may be energy and the specific area may be the sustainability of nuclear energy. For each one of those specific areas, perform some background research, using at least 2 sources per area.
7th Oct - 21st Oct (2019)	Evaluate the merit of each topic and identify the best one	Evaluate the pros and cons of each sub area when

		considering the requirements of the EPQ. Using this, decide the best topic area.
21st Oct – 4th Nov (2019)	Identify all resources needed for the project	Once the topic is decided, I need to determine what I will require to complete my project. This could include journal subscriptions and certain books.
21st Oct – 4th Nov (2019)	Formulate a research question	Using my guidance booklets, I will form a research question. I will meet with my supervisor to discuss this and amend the title if required.
21st Oct – 4th Nov (2019)	Create a clear set of aims and objectives	Given my title/ topic area, I will need to create an extensive list of aims and objectives to ensure a successful project. I will focus on meeting the EPQ criteria and fully exploring my topic. I should also focus on the skills I will need to acquire and utilise.
Continuous (7th Oct (2019) – 4th May (2020))	Gather research and maintain a bibliography	I need to be constantly gathering sources and adding them to my bibliography so that I can use them in my project. I aim to add 2 sources to my bibliography per week.
7th Oct – 18th Nov (2019)	Complete the EPF1 form and submit it to my form teacher	Each section of EPF1 must be fully completed.
4th Nov – 18th Nov (2019)	Review EPF1, making any needed adjustments based on feedback	If any areas are identified by myself or my supervisor, I will add to them as required.
18th Nov – 2nd Dec (2019)	Research project planning tools and identify a suitable one	I will research at least 3 types of project plans and evaluate the advantages and disadvantages of each. Hence, I will determine which one to use.
18th Nov – 16th Dec (2019)	Create a detailed project plan	I will break down my project into all of the individual tasks that together form the overall project. Using my chosen planning tool, I will set deadlines by which each task is to be completed by (and over how long a period each one is to be completed by). These targets should be SMART (specific, measurable, achievable, realistic, time-bound). I must allow some flexibility in time allocation to account for my studies.
Continuous (13th Jan – 24th Aug (2020))	Note down all changes to project plan when appropriate	Every time I deviate from my plan, I will note this down. For example, if I alter a deadline to be more realistic, I will note this down.

16th Dec – 30th Dec (2019)	Research citation methods and choose one to use for my project	I will look up multiple citation methods such as the Harvard refencing system and ultimately use one of them in my project.
30th Dec (2019) – February 10th (2020)	Create a detailed dissertation plan, splitting the topic down into smaller sub sections	I will split my large topic into several smaller sub sections, each addressing important parts of my topic. These will allow me to accurately allocate time limits and word limits to each section of the task.
February 10th – February 24th (2020)	Write an introduction for my project	I will write a brief overview on the topic and possibly each of the subsections.
February 10th – February 24th (2020)	Write and submit the first 1000 words/ sub section of my project	Write the first 1000 words of my EPQ ensuring that it fully meets the qualification requirements as well as answers the questions it needs to on the topic. This will then be submitted to my supervisor.
February 10th – February 24th (2020)	Write and submit the second lot of 1000 words	Write the second 1000 words of my EPQ ensuring that it fully meets the qualification requirements as well as answers the questions it needs to on the topic. This will then be submitted to my supervisor.
February 10th – February 24th (2020)	Third lot of 1000 words	Write the third 1000 words of my EPQ ensuring that it fully meets the qualification requirements as well as answers the questions it needs to on the topic. This will then be submitted to my supervisor.
February 24th – March 9th (2020)	Fourth lot of 1000 words	Write the fourth 1000 words of my EPQ ensuring that it fully meets the qualification requirements as well as answers the questions it needs to on the topic. This will then be submitted to my supervisor.
March 9th – 23rd March (2020)	Complete fifth lot of 1000 words along with a detailed conclusion and summary of dissertation	Write the fifth 1000 words of my EPQ ensuring that it fully meets the qualification requirements as well as answers the questions it needs to on the topic. This will then be submitted to my supervisor. I will also submit a conclusion that summarises my piece and all the research I have presented. Then I will reach a conclusion that answers my question.

15th June – 29th June (2020)	Re-read the whole dissertation and produce a second draft of the project.	Following a short break so that I have "fresh eyes" I will read over my dissertation myself and amend and alter the project where I feel it is required.
15th June – 13th July (2020)	Re-read the EPF forms and re-draft them where necessary, ensuring that they are all completed to a high standard	I will take all of the advice of my supervisor, the guidance sheets, the mark scheme and my own view of the forms following a re-read into account as I produce a final draft of the forms. I will ensure that all sections are complete and that any changes in my project are reflected in the forms. I will also update the "relevant documents" sheet. Then I will read them carefully to check for any errors.
15th June – 29th June (2020)	Ensure that at least 100 sources have been used and that everything is referenced in a proper way	I will ensure that each reference I have is referenced in the correct format and that I have analysed all of my sources in a bibliography to ensure that they are reliable. This is target is here to ensure that I have remained on track with my continuous task of gathering research and allows time for me to correct this if I haven't achieved it fully.
24th Aug – 7th Sep (2020)	Research presentation methods and practice speaking skills	I will research techniques that make an effective presentation, such as how much visual stimulus is effective. I will attempt to employ good oration and writing techniques when writing my script such as the rule of three.
24th Aug – 7th Sep (2020)	Produce a PowerPoint to accompany my presentation	I will make a PowerPoint to accompany my presentation. I will strive to include small amounts of important information on the slides for clarity and emphasis. I will strive to use visual stimuli over text when possible to ensure engagement.
7th September – 14th September (2020)	Discuss my draft and EPF forms with my supervisor	I will meet with my supervisor to discuss my forms and draft and note down any feedback given.
7th September – 21st September (2020)	Produce a third draft of the dissertation after re-reading guidance materials	I will re-read my dissertation once more. I will use the advice of my supervisor, that of the guidance sheets as well as the mark scheme to produce a final draft of my

		dissertation. I will then read this draft carefully to check for spelling and grammatical errors.
7th September – 21st September (2020)	Submit the dissertation and the EPF forms	I will submit the forms and dissertation, after having implemented any suggested changes from my supervisor.
7th Sep – 21st Sep (2020)	Prepare a script for my presentation	I will create a script that clearly reflects and summarises my topic. However, as the presentation is ten minutes it`s essential that I don`t fill it with too much information and ensure that it`s understandable and easy to digest. It should be engaging whilst still distilling the essence of my dissertation and reflecting it.
7th Sep – 21st Sep (2020)	Discuss my PowerPoint and script with my supervisor	I will discuss my script and PowerPoint with my supervisor, noting down any feedback given.
7th Sept – 21st Sep (2020)	Re-read my script and PowerPoint and produce a second draft of them	I will record myself giving a presentation and watch it back. Using this as well as re-reading it and considering both the EPQ criteria and my supervisor`s feedback, I shall amend both the script and PowerPoint where needed.
7th Sep – 5th Oct (2020)	Memorise my script and prepare for the presentation	I shall memorise the script and rehearse the delivery of it to ensure that it`s highly engaging.
7th Sep – 5th Oct (2020)	Read my dissertation and some sources to prepare myself for questions	I will re-read my script and dissertation. I will read some sources on my topic area to refresh my memory and prepare me to answer any questions that may be presented.
21st September – 5th October (2020)	Review and evaluate my project, analysing whether I have my met my aims and objectives and whether I would do anything differently	I will compare my aims and objectives and my project plan to what I achieved. I will take this all into account and evaluate how well I completed the project and which parts went well and which parts could have been improved.
21st Sep – 5th Oct (2020)	Do presentation	I will deliver my presentation that I have prepared for.
5th Oct – 19th Oct (2020)	Reflect and evaluate how well my presentation went	Following my presentation, I will reflect and evaluate how my presentation went overall.

Here is the current Gantt chart for the project plan:

Fortnight	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
Year	2019	2019	2019	2019	2019	2019	2019	2020	2020	2020	2020	2020	2020	2020	2020	2020	2020	2020	2020	2020	2020	2020	2020	2020	2020	2020	2020
Data Begir	07-Oct	21-Oct	04-Nov	18-Nov	02-Dec	16-Dec	30-Dec	13-Jan	27-Jan	10-Feb	24-Feb	09-Mar	23-Mar	06-Apr	20-Apr	04-May	18-May	01-Jun	15-Jun	29-Jun	13-Jul	27-Jul	10-Aug	24-Aug	07-Sep	21-Sep	05-Oct
Brainstorm and research potential research topics																											
Evaluate the merit of each topic and identify the best one																											
Identify all resources needed for the project																											
Formulate a research question																											
Create a clear set of aims and objectives																											
Gather research and maintain a bibliography																											
Complete the EPF1 form and submit it to my form teacher																											
Review EPF1, making any needed adjustments based on feedback																											
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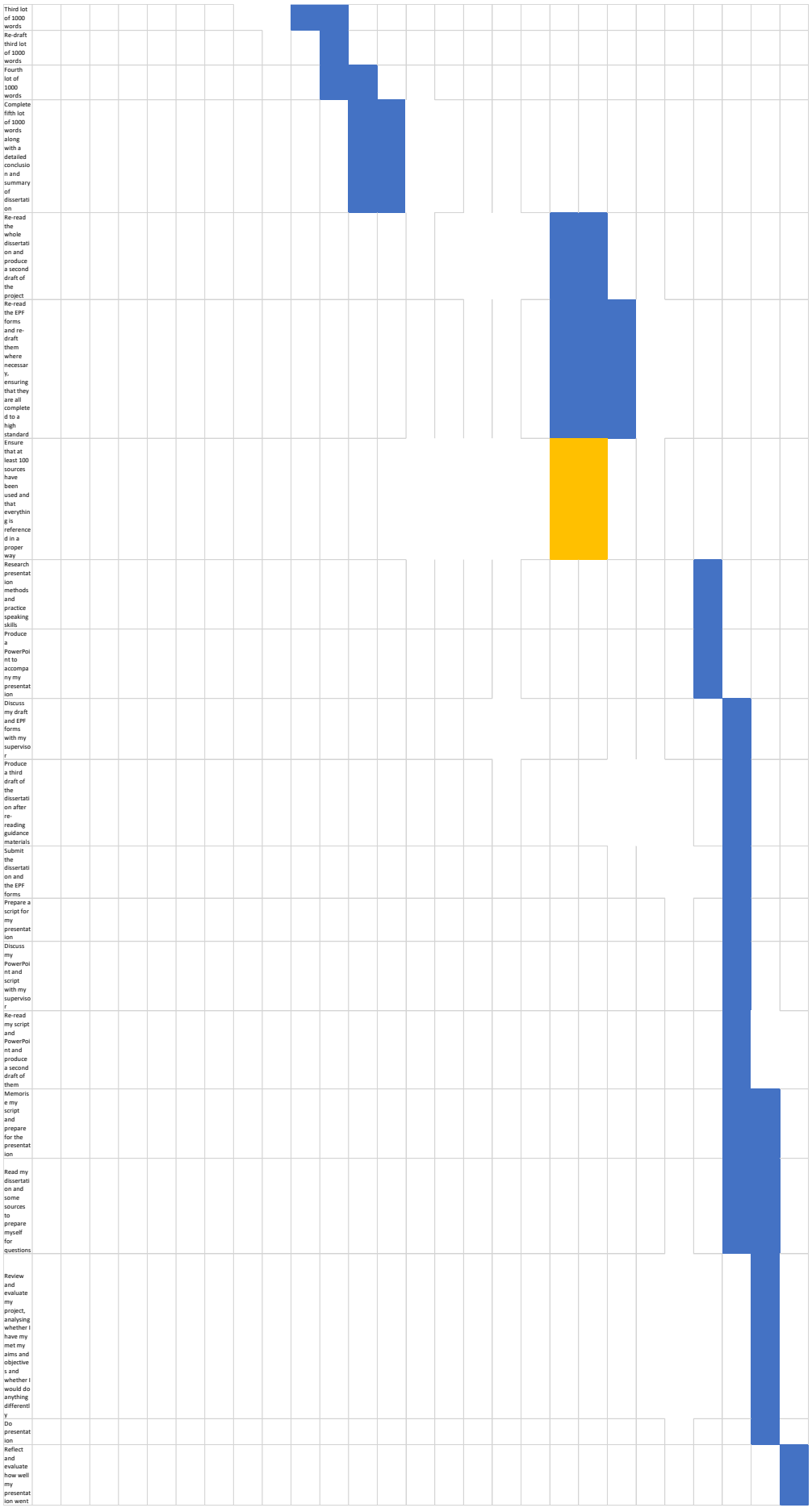
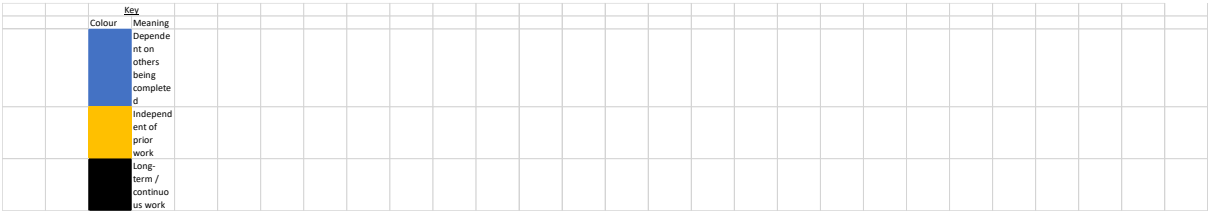

Third lot of 1000 words
Re-draft third lot of 1000 words
Fourth lot of 1000 words
Complete fifth lot of 1000 words along with a detailed conclusion and summary of dissertation
Re-read the whole dissertation and produce a second draft of the project
Re-read the EPF forms and re-draft them where necessary. ensuring that they are all completed to a high standard
Ensure that at least 100 sources have been used and that everything is referenced in a proper way
Research presentation methods and practice speaking skills
Produce a PowerPoint to accompany my presentation
Discuss my draft and EPF forms with my supervisor
Produce a third draft of the dissertation after re-reading guidance materials
Submit the dissertation and the EPF forms
Prepare a script for my presentation
Discuss my PowerPoint and script with my supervisor
Re-read my script and PowerPoint and produce a second draft of them
Memorise my script and prepare for the presentation
Read my dissertation and some sources to prepare myself for questions
Review and evaluate my project, analysing whether I have my met my aims and objectives and whether I would do anything differently
Do presentation
Reflect and evaluate how well my presentation went



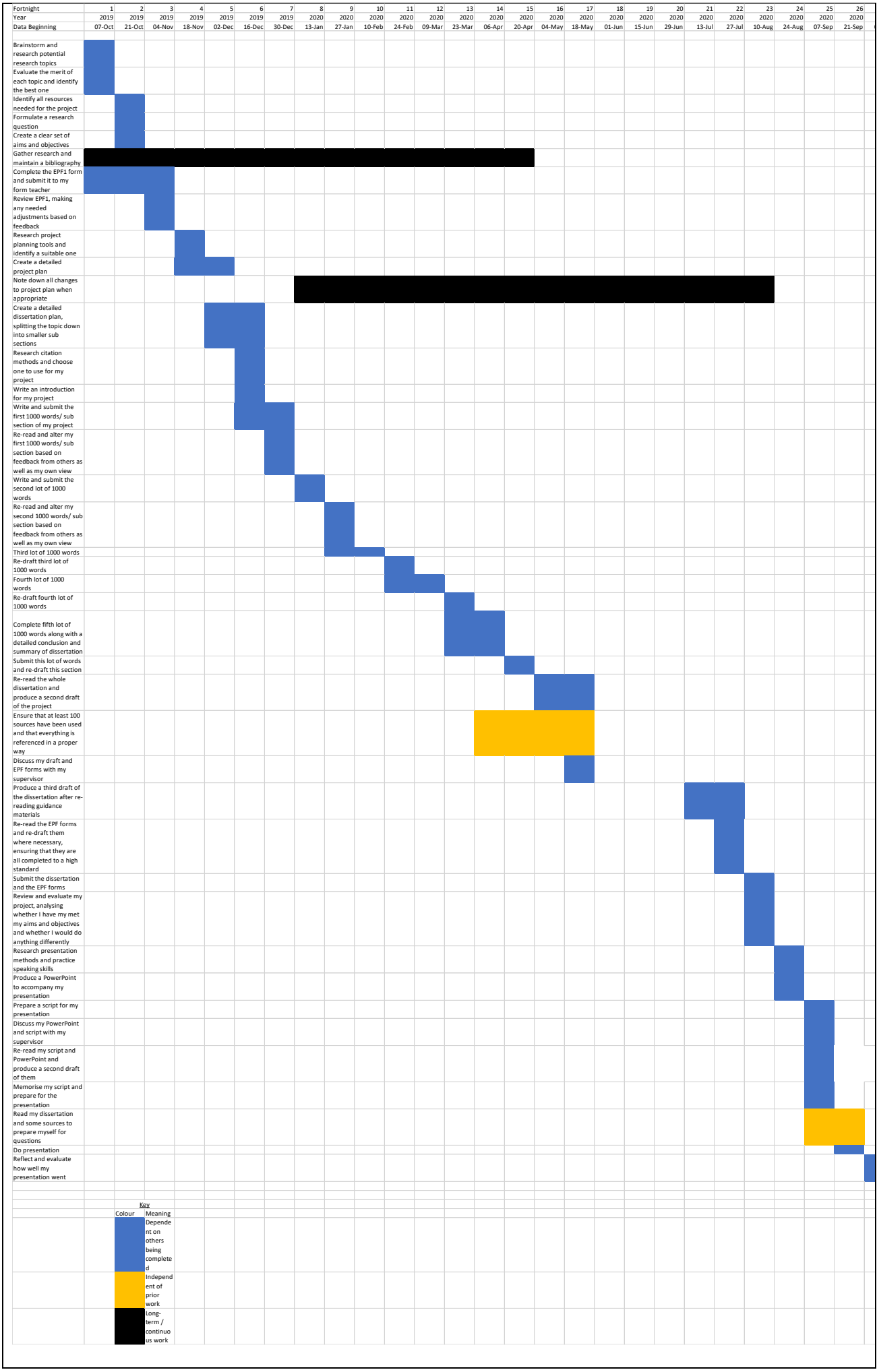
Alongside my project plan, I have also created a detailed dissertation plan. Following a talk on academic writing by Bath University, I have picked up valuable essay planning techniques. Hence, I shall include an overall word buffer as well as an overview of each aspect of my essay.

Paragraph “title”	Contents of Paragraph	Word limit
Abstract	A summary of the overall findings and contents of my piece. (This will be completed once I have written my dissertation).	100 words
Introduction.	The dictionary definition of artificial intelligence along with a brief overview of its applications which range of medicinal diagnosis to stock market prediction. I will briefly explain that these systems have both financial and societal drawbacks and advantages. I shall then to explain what I am exploring in my essay (i.e. the societal and economic contributions that AI makes and whether this is a positive or negative contribution).	200 words.
Explanation of AI	I will explain the basics of artificial intelligence, with a brief overview of neural networks and machine learning. I will use this broad overview to explain how AI systems can be applied to analysis of all kinds of data (probably using the example of image recognition due its ease of explanation). Through this explanation, the potency and drawbacks of AI should be made clear.	350 words
The use of AI in stock market analysis	Explain the use of AI in stock market predictions. They are very good at predicting smaller changes but struggle with drastic dips as they have insufficient input data to allow	350 words

	this to form part of their prediction algorithm. Due to the large use of AI, stock value may drop through no fault of company but due to similar (yet flawed algorithms).	
Detailed analysis of social and economic implications AI in stock market systems	Is it ethical to use them for analysis? Are they reliable enough? Is it wrong for AI to make money for people?	150 words
The role of data analysis systems in targeted advertisement and feed generation.	AI is used to create tailored advertising to a consumer. This could be argued to be a good thing as it ensures that adverts are simply more relevant to a user, thus being beneficial financially. However, the gathering of such data arguably comes at too much of a cost. AI is also used in social media to generate the content that viewers wish to see. However, some argue that the systems are incentivising addiction.	350 words
The use of behaviour analysis by states and whether the social implications from this are positive.	Brief explanation of potential uses of AI in surveillance on the masses to determine threats (highlight that none of this can be completely verified). Use of AI in financial irregularity detection. Discuss whether this is a positive social use as it probably keeps us safe but also facilitates mass surveillance and may potentially result in incorrect flagging.	250 words
Self-driving cars	Both Tesla and Google are in the process of creating self-driving cars and have many of them on the road (although they may not have been approved for full consumer access). Talk about the financial implications (e.g. for taxi drivers) and the potential social issues of a self-driving car, e.g. who is responsible if it wrongly kills someone? Should it deliberately kill its owner to minimise overall deaths?	300 words
Use of AI in breast cancer analysis and analysis of CT scans	A recent experiment shows that AI outperforms radiologists in diagnosis of breast cancer, which has social implications as it provides more accurate readings and frees up doctors	250 words

	to do more work. Should AI be given access to such personal scan results?	
Use of AI in medical consultation and record updating	AI is used to diagnose illnesses through an app that allows patients to describe their symptoms with their voice. A lot of specialist time is used up by updating and reading through medical records, and AI is used to reduce this time. Makes doctors more available however may not be entirely reliable for diagnosis.	300 words
Detailed analysis of the general economic impact of AI	I will use this section to analyse the overall financial impact AI has on society. I shall present the findings of multiple papers on the subject and discuss my overall takeaway.	400 words
Detailed analysis of the overall social impact of AI	In this section, I will analyse the overall impact of aim assessing whether it is positive or not.	400 words
Unknown	Due to the flexible nature of writing a dissertation, I have decided to leave some word count to a section that has not yet been planned. This is because I may discover something that I may wish to analyse in further detail when writing the previous paragraphs. If I cannot think of anything, I will simply write in more detail on the aforementioned subjects. This would also be quite a good situation as it is important that my analysis is detailed and of high quality as opposed to just mentioning many examples in little depth. This section also serves as the word buffer, as if I have written too many words, I can simply not do this section.	n/a
Conclusion	I will reach a conclusion on the overall societal and economic impact of AI in data analysis and medicine, explaining my view clearly and justifying it with examples I have used in my dissertation.	500 words

Additionally, my project plan has undergone multiple changes, so some of the old project plans are attached below.


Fortnight 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26
Year 2019 2019 2019 2019 2019 2019 2019 2020 2020 2020 2020 2020 2020 2020 2020 2020 2020 2020 2020 2020 2020 2020 2020 2020 2020 2020
Data Beginning 07-Oct 21-Oct 04-Nov 18-Nov 02-Dec 16-Dec 30-Dec 13-Jan 27-Jan 10-Feb 24-Feb 09-Mar 23-Mar 06-Apr 20-Apr 04-May 18-May 01-Jun 15-Jun 29-Jun 13-Jul 27-Jul 10-Aug 24-Aug 07-Sep 21-Sep
Brainstorm and research potential research topics
Evaluate the merit of each topic and identify the best one
Identify all resources needed for the project
Formulate a research question
Create a clear set of aims and objectives
Gather research and maintain a bibliography
Complete the EPF1 form and submit it to my form teacher
Review EPF1, making any needed adjustments based on feedback
Research project planning tools and identify a suitable one
Create a detailed project plan
Note down all changes to project plan when appropriate
Create a detailed dissertation plan, splitting the topic down into smaller sub sections
Research citation methods and choose one to use for my project
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Write and submit the first 1000 words/ sub section of my project
Re-read and alter my first 1000 words/ sub section based on feedback from others as well as my own view
Write and submit the second lot of 1000 words
Re-read and alter my second 1000 words/ sub section based on feedback from others as well as my own view
Third lot of 1000 words
Re-draft third lot of 1000 words
Fourth lot of 1000 words
Re-draft fourth lot of 1000 words
Complete fifth lot of 1000 words along with a detailed conclusion and summary of dissertation
Submit this lot of words and re-draft this section
Re-read the whole dissertation and produce a second draft of the project
Ensure that at least 100 sources have been used and that everything is referenced in a proper way
Discuss my draft and EPF forms with my supervisor
Produce a third draft of the dissertation after re-reading guidance materials
Re-read the EPF forms and re-draft them where necessary, ensuring that they are all completed to a high standard
Submit the dissertation and the EPF forms
Review and evaluate my project, analysing whether I have my met my aims and objectives and whether I would do anything differently
Research presentation methods and practice speaking skills
Produce a PowerPoint to accompany my presentation
Prepare a script for my presentation
Discuss my PowerPoint and script with my supervisor
Re-read my script and PowerPoint and produce a second draft of them
Memorise my script and prepare for the presentation
Read my dissertation and some sources to prepare myself for questions
Do presentation
Reflect and evaluate how well my presentation went
Key
Colour Meaning
Dependent on others being completed
Independent of prior work
Long-term / continuous work

Here is the accompanying table:

Start Date and Deadline	Targets and Milestones	Key Tasks and Activities
7th Oct – 21st Oct (2019)	Brainstorm and research potential research topics	Choose three possible broad topic areas. For each topic area, think of 3 specific elements of each topic for example, the broad area may be energy and the specific area may be the sustainability of nuclear energy. For each one of those specific areas, perform some background research, using at least 2 sources per area.
7th Oct - 21st Oct (2019)	Evaluate the merit of each topic and identify the best one	Evaluate the pros and cons of each sub area when considering the requirements of the EPQ. Using this, decide the best topic area.
21st Oct – 4th Nov (2019)	Identify all resources needed for the project	Once the topic is decided, I need to determine what I will require to complete my project. I will focus on resources such as reading material that may or may not be free to access.
21st Oct – 4th Nov (2019)	Formulate a research question	Using my guidance booklets, I will form a research question. I will meet with my supervisor to discuss this and amend the title if required.
21st Oct – 4th Nov (2019)	Create a clear set of aims and objectives	Given my title/ topic area, I will need to create an extensive list of aims and objectives to ensure a successful project. I will focus on meeting the EPQ criteria and fully exploring my topic. I should also focus on the skills I will need to acquire and utilise.
Continuous (7th Oct (2019) – 4th May (2020))	Gather research and maintain a bibliography	I need to be constantly gathering sources and adding them to my bibliography so that I can use them in my project. I aim to add 2 sources to my bibliography per week.
7th Oct – 18th Nov (2019)	Complete the EPF1 form and submit it to my form teacher	Each section of EPF1 must be fully completed.
4th Nov – 18th Nov (2019)	Review EPF1, making any needed adjustments based on feedback	If any areas are identified by myself or my supervisor, I will add to them as required.
18th Nov – 2nd Dec (2019)	Research project planning tools and identify a suitable one	I will research at least 3 types of project plans and evaluate the advantages and disadvantages of each. Hence, I will determine which one to use.
18th Nov – 16th Dec (2019)	Create a detailed project plan	I will break down my project into all of the individual tasks that together for the overall

		project. Using my chosen planning tool, I will set deadlines by which each one is to be completed by (and over how long a period each one is to be completed by). These targets should be SMART (specific, measurable, achievable, realistic, time-bound). I must allow some flexibility in time allocation to account for my studies.
Continuous (13th Jan – 24th Aug (2020))	Note down all changes to project plan when appropriate	Every time I deviate from my plan, I will note this down. For example, if I alter a deadline to be more realistic, I will note this down.
2nd Dec – 30th Dec (2019)	Create a detailed dissertation plan, splitting the topic down into smaller sub sections	I will split my large topic into several smaller sub sections, each addressing important parts of my topic. These will allow me to accurately allocate time limits and word limits to each section of the task.
16th Dec – 30th Dec (2019)	Research citation methods and choose one to use for my project	I will look up multiple citation methods such as the Harvard refencing system and ultimately use one of them in my project.
16th Dec – 30th Dec (2019)	Write an introduction for my project	I will write a brief overview on the topic and possibly each of the subsections.
16th Dec (2019) – 13th Jan (2020)	Write and submit the first 1000 words/ sub section of my project	Write the first 1000 words of my EPQ ensuring that it fully meets the qualification requirements as well as answers the questions it needs to on the topic. This will then be submitted to my supervisor.
30th Dec (2019) – 13th Jan (2020)	Re-read and alter my first 1000 words/ sub section based on feedback from others as well as my own view	Following feedback from my supervisor as well as re-reading it myself, I will then re-draft this section where necessary.
13th Jan – 27th Jan (2020)	Write and submit the second lot of 1000 words	Write the second 1000 words of my EPQ ensuring that it fully meets the qualification requirements as well as answers the questions it needs to on the topic. This will then be submitted to my supervisor.
27th Jan – 10th Feb (2020)	Re-read and alter my second 1000 words/ sub section based on feedback from others as well as my own view	Following feedback from my supervisor as well as re-reading it myself, I will then re-draft this section where necessary.
27th Jan – 24th Feb (2020)	Third lot of 1000 words	Write the third 1000 words of my EPQ ensuring that it fully

		meets the qualification requirements as well as answers the questions it needs to on the topic. This will then be submitted to my supervisor.
24th Feb – 9th March (2020)	Re-draft third lot of 1000 words	Following feedback from my supervisor as well as re-reading it myself, I will then re-draft this section where necessary.
24th Feb – 23rd Mar (2020)	Fourth lot of 1000 words	Write the fourth 1000 words of my EPQ ensuring that it fully meets the qualification requirements as well as answers the questions it needs to on the topic. This will then be submitted to my supervisor.
23rd Mar – 6th Apr (2020)	Re-draft fourth lot of 1000 words	Following feedback from my supervisor as well as re-reading it myself, I will then re-draft this section where necessary.
23rd Mar – 20th Apr (2020)	Complete fifth lot of 1000 words along with a detailed conclusion and summary of dissertation	Write the fifth 1000 words of my EPQ ensuring that it fully meets the qualification requirements as well as answers the questions it needs to on the topic. This will then be submitted to my supervisor. I will also submit a conclusion that summarises my piece and all the research I have presented. Then I will reach a conclusion that answers my question.
20th Apr – 4th May (2020)	Submit this lot of words and re-draft this section	Following feedback from my supervisor as well as re-reading it myself, I will then re-draft this section where necessary. I will also perform a spell-check of the piece as well as reading it over carefully to find any mistakes.
4th May – 1st Jun (2020)	Re-read the whole dissertation and produce a second draft of the project.	Following a short break so that I have "fresh eyes" I will read over my dissertation myself and amend and alter the project where I feel it is required.
6th Apr – 1st Jun (2020)	Ensure that at least 100 sources have been used and that everything is referenced in a proper way	I will ensure that each reference I have is referenced in the correct format and that I have analysed all of my sources in a bibliography to ensure that they are reliable. This is target is here to ensure that I have remained on track with my continuous task of

		gathering research and allows time for me to correct this if I haven't achieved it fully.
18th May – 1st Jun (2020)	Discuss my draft and EPF forms with my supervisor	I will meet with my supervisor to discuss my forms and draft and note down any feedback given.
13th Jul – 10th Aug (2020)	Produce a third draft of the dissertation after re-reading guidance materials	I will re-read my dissertation once more. I will use the advice of my supervisor, that of the guidance sheets as well as the mark scheme to produce a final draft of my dissertation. I will then read this draft carefully to check for spelling and grammatical errors.
27th Jul – 10th Aug (2020)	Re-read the EPF forms and re-draft them where necessary, ensuring that they are all completed to a high standard	I will also take all of the advice of my supervisor, the guidance sheets, the mark scheme and my own view of the forms following a re-read into account as I produce a final draft of the forms. I will ensure that all sections are complete and that any changes in my project are reflected in the forms. I will also update the "relevant documents" sheet. Then I will read them carefully to check for any errors.
10th Aug – 24th Aug (2020)	Submit the dissertation and the EPF forms	I will submit the forms and dissertation.
10th Aug – 24th Aug (2020)	Review and evaluate my project, analysing whether I have my met my aims and objectives and whether I would do anything differently	I will compare my aims and objectives and my project plan to what I actually achieved. I will take this all into account and evaluate how well I completed the project and which parts went well and which parts could have been improved.
24th Aug – 7th Sep (2020)	Research presentation methods and practice speaking skills	I will research techniques that make an effective presentation, such as how much visual stimulus is effective. I will attempt to employ good oration and writing techniques when writing my script such as the rule of three.
24th Aug – 7th Sep (2020)	Produce a PowerPoint to accompany my presentation	I will make a PowerPoint to accompany my presentation. I will strive to include little information on the slides but important information for clarity and emphasis. I will strive to use visual stimuli over text when possible to ensure engagement.

7th Sep – 21st Sep (2020)	Prepare a script for my presentation	I will create a script that clearly reflects and summarises my topic. However, as the presentation is ten minutes it`s essential that I don`t fill it with too much information and ensure that it`s understandable and easy to digest. It should be engaging whilst still distilling the essence of my dissertation and reflecting it.
7th Sep – 21st Sep (2020)	Discuss my PowerPoint and script with my supervisor	I will discuss my script and PowerPoint with my supervisor, noting down any feedback given.
7th Sept – 21st Sep (2020)	Re-read my script and PowerPoint and produce a second draft of them	I will record myself giving a presentation and watch it back. Using this as well as re-reading it and considering both the EPQ criteria and my supervisor`s feedback, I shall amend both the script and PowerPoint where needed.
7th Sep – 21st Sep (2020)	Memorise my script and prepare for the presentation	I shall memorise the script and rehearse the delivery of it to ensure that it`s highly engaging.
7th Sep – 5th Oct (2020)	Read my dissertation and some sources to prepare myself for questions	I will re-read my script and dissertation. I will read some sources on my topic area to refresh my memory and prepare me to answer any questions that may be presented.
21st Sep – 5th Oct (2020)	Do presentation	I will deliver my presentation that I have prepared for.
5th Oct – 19th Oct (2020)	Reflect and evaluate how well my presentation went	Following my presentation, I will reflect and evaluate how my presentation went overall.

Comments from Supervisor:

Endorsed by: _____ **Date:** _____

EPF **2b**	**CHANGES TO PROJECT PLAN**	

CHANGES TO PROJECT PLAN

Any changes to the Project Plan during the development of the project should be recorded on a separate sheet. A sample template is provided below. Learners can adapt the form below and tailor to their needs. You must also record in detail, why you made those changes.

Dates	Changes to Initial Project Plan
2nd February 2020	I have altered my timetable to reflect the fact that I have examinations throughout May and June and hence I have decided that I won`t do any work on EPQ after March so that I can adequately study for these examinations.
4th February 2020	Upon re-reading my project plan, I have decided that many of the dates are unrealistic. External factors have also forced me to change my plan as my supervisor recommends that I write my first section of the dissertation by February 24th. My supervisor also advises that I complete my first draft by March 23rd and hence I have updated my plan accordingly.
8th February 2020	I have decided that constantly re-drafting my EPQ as I am writing it is unfeasible and hence, I shall focus on writing it first and then reading over and redrafting it once I have completed a draft.
18th February 2020	Upon researching dissertations, I have decided that I wish to include an abstract and table of contents in my dissertation. I have updated my rough essay plan accordingly.
5th March 2020	Due to upcoming examinations, I will not complete my first draft of my EPQ by March 24th as I have been advised to focus all of my available spare time on revision. As such I have updated my plan to reflect the fact that my EPQ will likely be completed over summer instead.
8th May 2020	Due to the current COVID-19 pandemic, the timings of my EPQ have changed significantly. I am finding that despite the lack of examinations, my daily schedule is still very busy and as such I still feel that it is likely that my EPQ will be completed over summer. However, I feel that I can dedicate a larger portion of time to my project during what would have been exam period (even if I still need to spend time revising all of my subjects). Hence, I feel that it is a realistic goal to have written a first draft of my EPQ and have re-drafted it by late August.
22nd May 2020	Having started my dissertation, I have concluded that I will not follow the essay plan in my project plan. This is because I have now performed extensive research into AI in data analysis and healthcare and have identified areas such as atrial fibrillation detection and use of AI for targeted advertisement. I feel that these areas are my suitable to assess the overall socio-economic impact of AI. I also have found that the structure of my essay plan is poor as it uses a large number of examples but does not focus on any specific example in enough depth, leading to lots of superficial analysis, but not enough deep level assessment of resources and impact. Therefore, my essay will focus on far fewer examples of AI use but analyse these in far greater depth to determine the overall socio-economic impact of AI in these fields.

1st June 2020	Having worked hard on my dissertation, I have decided to change my title from " To what extent do the use of artificial intelligence systems in medicine and data analysis contribute to the socio-economic condition of society?" to " To what extent do the use of artificial intelligence systems in medicine contribute to the socio-economic condition of society?". This is because my dissertation would be far too long. There is more than sufficient research to analyse AI in healthcare alone. I feel that this approach allows me to provide a more detailed and ultimately more accurate answer, as opposed to focusing on two large fields and being unable to sufficiently analyse either. My dissertation needs to be re-drafted somewhat to reflect this. Guidance from the EPQ coordinator says that it is ok to change the title of my EPQ slightly without getting it reapproved. Furthermore, I feel that it is far harder to assess the overall socio-economic impact of AI in data analysis as it is so widely used in the field, whilst its use in medicine is much smaller.
8th June 2020	Upon meeting with my supervisor, I have decided that I shall finish my first EPQ draft by 19th June 2020.
19th June 2020	Having worked hard on my EPQ draft for two weeks, I have not quite finished it. However, I am very close to completion. I have read some of the guidance material provided by our college which suggests that dissertations include a source evaluation. This will take quite a bit of time as I have nearly included one hundred sources already. Therefore, I am giving myself until the 24th of July to complete my dissertation draft and source evaluation. This large window is in part due to the fact that I have an online summer school that I also plan on attending as well as homework.
24th July 2020	Having completed my source evaluation and dissertation draft, I plan to complete my remaining EPF segments and presentation by the time we return to college in September.

Note: Please add or delete rows depending on your requirements.

EPF 2c	EXTENDED PROJECT RECORD AND REVIEW OF TEACHING & LEARNING PROGRAMME	

Learners should record in detail **at least three areas** of the teaching and learning programme that influenced and contributed to the project outcome.

Note: Please increase the size of the boxes or add more rows as required.

Dates	What I learned from the teaching programme	Review and reflection
October 2019	In this programme, we learnt about how to research various topics and asses these to produce a good question for our project title. I learnt that performing basic research into a decently wide range of topics would help me assess which topics I found interesting and could realistically write an essay on.	As a result of this talk, I researched a range of broad concepts such as quantum mechanics, artificial intelligence, and mathematical proofs to determine which topics where both interesting and widely researched. As a result of this, I was able to discount some topics straight away as I realised that they were too advanced for me to understand and talk about in around 5000 words. This technique of reading around a topic helped me greatly in my EPF forms where I had to assess various topics and pick one. It also helped with my formation of a title as I was able to determine the areas of a subject that was interested in through reading widely about them. This broad reading around the subjects was useful as it meant that I had already developed an image of AI in healthcare before I started writing the essay.
October 2019	In this session, we had an academic come in and explain a range of useful skills related to dissertation writing. The academic focused particularly on evaluation of a source and how to effectively perform research. Through this session, I was introduced to CRAAP analysis, an approach to assess the validity of a source by analysing its currency, relevance, authority, accuracy, and purpose. I learnt that the resource medium can be indicative of reliability with resources that anyone can contribute to such as blogs or Wikipedia being of less validity than something produced by experts such as an entry into an academic journal. I was also introduced to Google Scholar in this session, a search engine which is used by academics to search for relevant academic papers, filtering out typically less reliable resources such as opinionated news articles. I embraced a wide range of new technologies in this session, becoming familiar with advanced search options such as Boolean	From this talk, I was able to determine the validity and usefulness of a source more reliably. Before, I primarily considered the content, author, and purpose of a source, but I now consider a wider range of things such as when it was published, the reliability of the medium and how relevant a source is. The discovery of Google Scholar is invaluable for me as it has allowed to identify the suitability of a topic much more effectively (by helping me see the levels of academic research that are present around a particular topic). When producing my project, Google Scholar was invaluable as Artificial Intelligence is a field which contains a large number of unfounded opinions published by people with little expertise in the field. Google Scholar allowed me to avoid these and instead focus on serious academic research, which is far more relevant. When assessing AI in healthcare, it was important to use academic papers, as healthcare is a field which requires high-level expertise (and thus blogs are likely to be less

	operators (operators which could be used to highlight articles containing “AI” or “artificial intelligence”, for example). I also enhanced my critical reading skills, as we were all given extracts of medicinal articles and we had to determine the validity of the resource, applying the CRAAP analysis. Through this, I developed my critical thinking skills and became much more proficient at identifying useful and reliable sources. Conversely, I also become more skilled at identifying sources that are not as reliable and useful.	valid as the expertise of an author is not verifiable). Advanced search terms helped me, particularly as many papers used one of two phrases to describe the same thing (e.g. “AI” and “artificial intelligence” or “AF” and “atrial fibrillation”). My critical reading and thinking skills were sharpened through the reading of texts in a critical light, something which was very valuable when reading hundreds of resources and deciding which ones were valid. It also taught me how to approach two valid resources that present differing viewpoints, something which was very relevant when assessing the socio-economic impact of AI in healthcare.
October 2019	Through use of resources provided by my College, I was able to learn about how to construct an effective plan. I was shown a video on effective target setting using SMART targets. A target is SMART if it is specific, measurable, achievable, realistic and time bound. This is important as plans with typically vague and non-specific details typically fail. For example: “Write introduction” is much harder to achieve than “Write 200 words summarising the potential of AI systems in healthcare by 1st July 2020”. This will be useful for me as I struggle to follow non-specific targets and as I am good at working towards a deadline. Through, past examples and recommendations, I have identified a range of possible technologies to consider using when creating my project plan such as a GANTT chart. Upon viewing past examples, I have gained a deeper understanding of how to create an effective plan and have understood the importance of breaking down of a task into individually achievable things (e.g. break down “write essay” into “write 300-word introduction on AI by 1st July 2020”).	From my own exploration of digital resources from the WJEC website, exploration of resources provided by College and sessions provided by College, I was able to gain an understanding of what makes an effective project plan. I assessed multiple methods of project plan such as a PERT chart, but I choose to use a GANTT chart in combination with a table in the end. Through the programme, I learnt the visual value of a GANTT chart, which provides a highly intuitive sense of when each task should be completed. Using a table with this allows me to break each target down in detail and make it sufficiently SMART. The creation of an effective project plan has been massively beneficial for me as it has given me sense of what I should be doing and when by and has allowed me to become independent and take control of my completion of the task. However, my project plan was not perfect and had to be altered a few times as I had not always set myself realistic time windows to complete certain tasks. The COVID-19 pandemic also made my plan less useful as much of it had to be changed to account for the unexpected circumstances. However, despite this the programme helped me produce an effective project plan which has enabled me to complete each section of the EPQ in a reasonable time frame.
November 2019	A group of academics came in to talk to us about the importance of referencing in essays (and the legal requirement to do so). Common referencing techniques such as Harvard referencing, and numerical based referencing were discussed. It was highlighted that an established referencing technique should be used and that the author(s), publisher, title, and method of identification (e.g. hyperlink) should be identified where possible. Merits of the Harvard referencing style where highlighted as it was typically enabled a reader to get more of a sense for the resource being	This talk was highly useful as it showed me the need to reference and introduced me to two useful referencing styles. I ended up choosing numerical referencing as I felt that it was a more aesthetically pleasing format that led to more organised resources and made it easier for users to access a given resource. I also learnt the importance of keeping track of also resources used, something which was highly useful for me when I performed my source evaluation as I had a copy of all resources I did and did not use. Without this programme, I really probably would not have used an appropriate

	described. Numerical sourcing was also described, and it was highlighted to be advantageous as it was easier to reference the same source multiple time and created a more structured bibliography. Resources were also highlighted that kept tracked of all sources one had read in a format such as Harvard referencing by simply clicking a button. This made it far easier to keep track of all resources being read. I also learnt about copyright and plagiarism, showing the importance of referencing, and only reusing large chunks of work (such as an image) with permission.	referencing format which would have led to a poor essay. As a result of this session, I was able to cite all sources in an effective manner, something which I feel I did really well throughout my dissertation.
November 2019	A talk from an academic at Bath University was given about essay writing skills such as structure, planning and word count management. He described the structure of typical essay to include an abstract, an introduction, a main body, and a conclusion. Effective analysis of sources was also discussed. We were shown examples of high quality and poor sources and we had to identify which were which and why. This built on my knowledge obtained in the CRAAP session and helped me to effectively articulate why I felt a certain source was valid or not. The purpose of an abstract was explained (as a brief summary of the findings of the dissertation) and the talk really enabled me to understand precisely what I need to include in my dissertation and what each segment means. He also talked about techniques to use when planning a dissertation. He suggested splitting an essay into introduction, paragraph 1, paragraph 2 (etc.) and a conclusion. One should roughly label what one wishes to talk about in each paragraph and using this, one can assign a rough number of words to use in each section. It was recommended that roughly 10% of the word count was not allocated and that this served as a buffer so that if one went over the desired number of words in a paragraph, one was still within in the desired number of words.	This talk was very useful as it helped me to structure my dissertation and produce a rough outline of what I wanted to include in my dissertation and where. In my project plan, I produced a rough dissertation plan using the work allocation techniques described in this talk. As a result of this, I was able to understand and include an effective abstract in my dissertation that effectively summarises my essay. As a altered my project title slightly, I was unable to use the word allocation draft very effectively, however I did still make use of it to determine roughly how many words I needed in each segment of my EPQ. I feel achieved this well as my dissertation is about 8000 words which my tutor said was an acceptable length assuming the content is focused (which I feel it is). The analysis of what makes a source good or not built on my prior knowledge and really helped when assessing conflicting sources and whether a source was of significant validity to use in my project. The furthering of my critical thinking and analysis skills in this talk was important as high-level analysis was something that I used a lot in my essay, particularly when using sources to assess overall impact.

EPF 2d	EXTENDED PROJECT RECORD AND REVIEW OF INDIVIDUAL PROGRESS	

During the development of your project, you should record and review **at least three milestones/SMART target** that you have achieved, altered or not achieved referring back to your Initial Plan. You must also record in detail, any action(s) taken in responding to the challenge(s) or in solving the issue(s).

Note: This should be used in conjunction with your Project Plan. Please expand boxes or rows as required.

Dates	Milestones & Targets Achieved, Altered or Not Achieved	Review & Actions Taken
30th October 2019	I have performed initial research into a range of fields that I may wish to write my dissertation on, including quantum mechanics, artificial intelligence, and methods of calculating pi. I have assessed a range of research available on each of the subjects and have done so in a good time frame.	After having read around these topics, quite a bit, I have found which areas I am interested in. For example, I found that I was interested in quantum mechanics but that the science behind it was too complex for to understand. Methods of calculating pi intrigued me more, with complex infinite series replacing crude methods such as creating many sided polygons. I was also interested by the idea that a perfect circle may not actually be possible due to the fact the Planck length is the smallest possible length of an object). Therefore, circles may only be a mathematical concept that is not fully replicable in the real world (although humans can get close enough to the point where this is irrelevant). However, most intriguing was my research into AI. I would say my research was highly successful as I gained a good overview of each topic. However, I feel that I should research more academic papers on each topic, particularly looking for topics where disagreement exists. I shall continue following my plan as before and will research more specific and more academic elements of AI and pi calculation to decided what which topic I shall use for my dissertation.
16th November 2019	I have now come up with a question that I wish to write my EPQ on. I have written a set of aims and objectives that I aim to achieve throughout this process. These include the use of new technologies and producing a coherent and well-structured essay on the potential future developments of artificial intelligence. I have achieved this in the anticipated timeframe.	I am pleased with the topic I have come up with, however I do feel that I may struggle to assess the future impact of AI, so I have decided to assess this by evaluating developments of AI over time. My objectives reflect this by ensuring a use of many academic resources, which are primarily about current and past AI capability. I shall continue finalising my EPF one forms and show them to my

		supervisor to obtain feedback. I will also submit my project title for approval.
23rd November 2019	I have now completed my first draft of all the EPF 1 forms to what I feel is a very high standard.	I am pleased as I have completed my EPF 1 forms in good time and have done them very well I feel. I initially found it difficult to imagine what resources I would need to complete my project, but upon looking at a few past projects (provided by my College), I was able to produce a comprehensive list. I also was able to understand the wide range of mediums that should be utilised in a dissertation. So far, I have performed well and am one time. I plan to continue my hard work and will re-draft my EPF form upon meeting with my supervisor.
9th December 2019	I have now created a detailed and comprehensive project plan that sets a range of SMART targets to be completed by specific dates. This will allow me to complete my EPQ in an effective manner and help me understand what I should be doing and when by. I have also included a rough essay plan that details what I may wish to write in a specific paragraph and how many words this will take.	I am very happy with my project plan, which I feel is comprehensive and thorough. I researched three technologies to produce the plan and initially used a GANTT chart. However, I felt that the GANTT chart was effective at providing an effective visualisation of a timeline but that it did not allow to explain each target in detail (and thus make it SMART). Therefore, I used a GANTT chart in combination with a table, making use of the visual clarity of a GANTT chart and combining it with the detail of a table. Determining which software to use for my chart was also difficult, particularly as I was producing a plan that would cover about a year. I explore several pieces of software, but ultimately choose Microsoft Excel as I had ready and free access to it. I also am still not entirely familiar with all elements of the EPQ and may have to adapt my plan if my understanding of the forms changes. I also feel that my essay plan may prove ineffective as one typically changes directions when researching a topic in detail. However, the word management part is certainly a very useful technique. I feel that the plan is well-thought out in terms of timing (accounting for examination period) and that the targets are SMART and detailed enough to enable me to understand what I need to do. I shall continue as planned and present my project plan to my supervisor.
9th January 2020	I have met with my tutor to go over my EPF1 forms and have noted the feedback given in the records of meetings with my supervisor. My tutor felt that I had completed the form to a high level of detail. However, following a review of my subject choice it was recommended that I shift the project to a focus on current AI uses and their	Following the review of my EPF 1 forms with my tutor, I shall re-read all of my EPF 1 forms and update them all where necessary by next week. I shall keep in the old parts of my form that discuss a project about future uses of AI, but I shall add to them to show my justification for the new topic. Leaving in the old segments shows my academic process,

	contribution to society as opposed to the potential future capabilities of AI. When reviewing my EPF 1 forms, my tutor noted that my aims and objectives had not been updated to reflect this. Apart from this, the feedback was very positive.	an important aspect of the qualification. However, I am very much pleased with the feedback which shows me that I am doing pretty well. The review also shows me how important constant updating of my form is when I change my project. This will be an important principle to remember when noting down changes to my project plan. It is important that I complete my redrafts of EPF 1 this week in order to remain within the time frame for the project.
5th March 2020	I have redrafted my EPF1 forms and gone over my project plan with my supervisor. My supervisor concluded that my plan was of high quality and was suitable. It was pointed out that I will realistically be unable to do much EPQ work in the next few months so that I can focus on the completion my examinations. As a result of this, I have altered the timeline of the completion of my first draft of my EPQ slightly. I have also re-read and rewritten my EPF 1 forms to account for the new direction I am taking with my project. Admittedly, the redraft took longer than I expected but I remain on schedule as I completed my plan in good time.	Following the review of my project plan, I have adjusted the dates slightly to account for the fact that I am only allowed to hand in one draft and that this will be realistically done in Summer as I need to focus on my A-level study. I have also decided to reformat my GANTT chart slightly so that it is more readable from a word document. I have also come to realise the limitations of the GANTT chart as it loses some of its visual clarity if it is a plan that spans a large period of time. So, I have altered my target completion date of the first draft of my EPQ to be around June / July.
19th June 2020	In the wake of the COVID-19 pandemic and the subsequent changes to College and life that have occurred, the deadline for the first draft of the EPQ was altered. My supervisor discussed when I should hand in the first draft of my EPQ. We agreed on a date of the 19th of June. However, I have unfortunately been unable to achieve this due to various summer schools and due to other homework. However, I have almost finished the project and have written about 85% of the dissertation. I anticipate finishing the remaining aspects of the dissertation in the next two weeks.	I have had to alter my project plan and the date when I will hand in my EPQ. I will make sure to continue my work rate so that I can hand in the next draft in as soon as possible. I know that I need to work hard as my ultimate target is to have finished my EPQ by summer (except for the actual giving of the presentation) so that I can focus on what will be a difficult academic year. Although I have not reached the deadline, which I am disappointed by, I have been working very hard on my draft and I was simply unable to do it in the time. My tutor acknowledge that the deadline may be slightly fluid. Therefore, I resolve to continue to work very hard on my dissertation and wider project to ensure that I have the finished my project and all schoolwork by the end of summer (so that I do not have to start a difficult school year already behind on work). I will use the extra time to re-read my dissertation and ensure that it is completely focused on the subject. So far, I have had to overcome a range of issues. For example, I initially was planning on assessing the impact of AI in healthcare and data analysis, but I found this left me with an essay that lacked focus and high-quality analysis. Hence, I decided to just

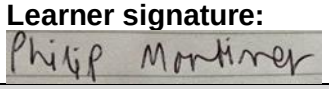
		focus on healthcare. I choose healthcare over data analysis as there was a greater amount of academic research into the field (and hence high-quality resources). I initially found it difficult to get acquainted with the medical language used to describe accuracy of systems such as specificity and sensitivity, but I was able to solve this by watching a YouTube video of a lecture that explained basic medicinal terms.
24th July 2020	I have completed the first draft of my dissertation. This has taken me longer than anticipated, but I feel that I have produced a draft that is of really high quality. I was not able to complete it in the two weeks I had set myself initially, however this is because I read over the College guidance once more and discovered that one was expected to include a source evaluation at the end of the EPQ. This does not count towards the word count but is still considered a part of the wider process. I decided that I would include this when I submitted the dissertation to my supervisor. However, this took a great amount of time as I had to evaluate the merit of each of the resources used as well as their reliability and validity. As I used over 100 sources, this naturally took a long period of time. However, whilst I had to alter the deadline, I feel I have met the aims and objectives that relate to my dissertation and met all of the criteria for the essay. In short, I am satisfied with my essay and have submitted it to my supervisor.	Despite the high quality of my essay, it took me far longer than anticipated to produce. As a result, I have concluded that I need to focus the next three weeks on my EPQ so that I can get all of the forms done by mid-August. If I achieve this, this will give me adequate time to do all of my summer homework (of which I have rather a lot of). Therefore, it is important that I maintain my level of hard work and complete as much of the EPQ process as possible by September. I will particularly focus on finishing my presentation and re-drafting my EPQ based on feedback from my supervisor as well as from me re-reading it.
7th August 2020	I have now produced a PowerPoint and script for my presentation on my EPQ. The presentation covers my whole academic process, including my aims, the conclusion of my dissertation and how it was reached, and evaluation of how successful my project has been. I feel my presentation is of a great standard and is engaging and accurate, providing a thorough overview of my project. However, I have not yet heard back from my supervisor, so I will have to alter the presentation somewhat when I re-draft my EPQ. However, I do not anticipate that I will have to change the presentation drastically.	I am pleased with my time management skills as I have worked really hard and have now completed everything bar the re-draft of my EPQ and the delivery of my presentation. Once, I receive feedback I shall re-draft my dissertation and alter my presentation accordingly (however I do not anticipate large changes to the presentation being necessary). I am pleased with my presentation and I am pleased with the fact that I now back on track in terms of time scale for my project (having spent more time than anticipated on my first draft of my dissertation). I will now redraft my EPQ once I receive feedback, perform the final meeting with my supervisor and deliver my presentation.
3rd September 2020	I have received feedback from my tutor on my project. My tutor says that my essay is bordering on being too long and that I have to use Harvard referencing when referencing. I have implemented	I have nearly finished the entire project process and am pleased with all of my work. I am also pleased that I am on schedule, something which is important given that I return to College next week. I

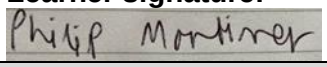
	these changes and re-drafted my EPQ. I have reduced the length of the dissertation from about 8700 words to 6900 words. I have also updated all my references to make use of the Harvard referencing system as opposed to the number system I was using before.	learnt the importance of being succinct and making focused points through my cutting down. I also felt that I used referencing more appropriately following the switch to Harvard referencing. My tutor said that apart from the length and referencing, that it was "very good overall" and that I discuss the question very well. I am pleased with this, as I have put a lot of effort in and feel that my dissertation is of high quality.
6th January 2021	I have now given my extended project presentation. Whilst I achieved this later than anticipated, this was due to my supervisor suggesting that the presentation be performed in January. I gave a speech on my dissertation and wider project process which was accompanied by a PowerPoint.	I feel that I have achieved my targets for the presentation as I feel that my presentation was very well delivered. I feel that my speech did a great job at summarising my project outcome as well as reflecting and reviewing my entire project process. I was able to come to terms with new technologies in PowerPoint – making use of animations and design ideas- to create what I feel is a very high-quality presentation. I enhanced my summary and speech giving skills and I feel that I was able to meet all of the requirements for the EPQ presentation to a high standard. I am pleased with my progress and have completed all of my project, well ahead of an internal deadline provided by the college of the 1st of February. I shall re-read all my EPF forms one more time and re-draft where necessary, however I have done this throughout the project and do not anticipate making any major changes. I am extremely pleased with my entire project and I feel that I have general met my deadlines (although some deadlines did have to be delayed due to unforeseeable external factors caused by the COIVD-19 pandemic).

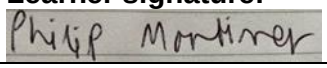
EPF 2e	EXTENDED PROJECT RECORD OF MEETINGS WITH SUPERVISORS	wjec cbac

Records to be completed by the student.

Note: Issues discussed, outcome of meeting/ interview and actions agreed should be recorded. Please adapt the form as per your requirement and attach records of any additional meetings.

Date	Initial Interview	
09/01/2020	In my first meeting with my supervisor, we went over my EPF1 form and discussed it. This meeting was conducted after my project title had been changed to focus on the contribution of ai to society. My supervisor stated that the focus on current uses was a good idea and that there were certainly enough resources to satisfy the scope of the project. When reading through my aims and objectives, my supervisor stated that they were very good on the whole but that the first aim and its corresponding objectives could do with updating. This was because it failed to reflect the fact that the focus of my project had shifted and was longer analysing the future developments of ai. Hence, I will re-read all of my aims and objectives and alter the first set to reflect the new focus. My supervisor also mentioned that one or two of the targets could do with being more SMART (Specific, Measurable, Available at an acceptable cost, Relevant and Time-bound). I will bear this in mind when updating my aims and objectives. As a result of the fact that I forgot to update my aims and objectives to match my new title, I have decided that I shall re-read, and where necessary re write, all of my EPF1 with this in mind. My supervisor was pleased with the fact that I had filled in the form in such detail. However, she correctly pointed out to me that I will need to be conscientious to ensure that when I write the actual dissertation, I will need to remain close to 5000 words. My supervisor also noted that whilst my piece was very detailed, it is very important to manage my time well so that my A-level studies do not suffer. Finally, we read over the additional documents section of EPF1 where I included my reading log that I used for the form. We agreed that the format wasn`t great as some of the table was cut of the page. I will try to fix this; however, this may be difficult so I may just have to have the table in raw text form (which isn`t very aesthetically pleasing). I inquired where I can add my reading log/bibliography and my supervisor said she would clarify that when the time came. I highlighted the changes that I would make as a result of the meeting and my supervisor told me it was important to note all changes made. Hence, at sections where I make minor changes, I will say something like “following feedback” and sections where I make larger changes, I will include screenshots of the original. I will seek to make all of the outlined changes as soon as possible, so I will set a deadline of the 16/01/2020 (a week). I will prioritise updating the aims and objectives and the EPF1 form as I will need to keep my aims and objectives in mind during the writing of my dissertation. Whilst I will end up ensuring my reading log is in the proper format, this is less of an immediate priority as it is a working document that will be updated frequently. Following this, I hope to get my plan done in good time so that I am in a position to start my project by late January at the latest (if all goes well).	
	Learner signature: 	**Supervisor signature:**
Date	**Mid-Project Review**	

05/03/2020	In this review, I went over my project plan (and changes to plan) with my supervisor. The general feedback was positive as I had discussed the advantages and disadvantages of multiple planning methods and had been thorough with my planning and dates. My supervisor said that the format was appropriate however, it was noted that the Gantt chart was difficult to view digitally. However, we concluded that it would probably be very readable when viewed physically. Hence, I have resolved to print this section out to determine whether one can read it or whether I may need to reformat and/or alter my planning method. My supervisor said that my actual plan was thorough and seemed to be of a high standard. Furthermore, my supervisor noted that a dissertation plan wasn`t essential, however something that is really useful and a great thing to have. I was encouraged to focus on studying on my A-levels and not to do any/ a lot of EPQ outside of my form time slots. My supervisor shared my view that the EPQ will be primarily completed over summer and that studying now is important. My supervisor concluded that my dissertation plan was very good as it is a useful tool to remind of what I wish to write about when I come to writing my dissertation over Summer. My supervisor noted that it was prudent to include a large word buffer in the plan and to acknowledge the fluidity of the plan as I may realise certain topics are less appropriate when actually writing the dissertation. Finally, we reviewed my changes to the plan, and it was noted that I had done well and that it was important to keep this section up to date. My primary takeaway is that I need to continue to update my project plan depending on whether dates are met and note this down in the changes to project plans section. I have also resolved to update my project plan to reflect the fact that I won`t be completing my first draft of the dissertation by March 24th and the I won`t be doing any EPQ/ very little EPQ through March, April, May and some of June to revise for my examinations.	
	Learner signature: 	**Supervisor signature:**
Date	**Final Interview**	
19th August 2020	My supervisor discussed my first project draft with me in this final meeting. My supervisor says the project was very good overall and that the question is a great one to discuss. My supervisor commented that I discussed the question very well. Generally, my tutor seemed to think that my draft was of high quality. My supervisor mentioned one or two things that could be changed such as the use of the term “digitally literate”. I will update this to “technologically competent” to make the meaning clearer. My supervisor commented on the fact that I was using numerical referencing and stressed that it was mandatory for me to use Harvard referencing. As such, I strive to update my essay to make full use of Harvard referencing in the next week. My supervisor attached a sheet which explains how to utilise Harvard referencing as well as a copy of an essay my supervisor had written, to demonstrate how to properly reference. My supervisor said that Harvard referencing, and the length of the essay were the only two major issues in the dissertation. My supervisor commented that my essay was bordering on being too long, sitting at ever slightly over 8000 words. However, my supervisor acknowledged that it was only bordering on being too long. I was shown WJEC guidance which states that “*Learners will not be penalised for going over the 5000 words. If, however, learners went way beyond the 5000*	

	words, e.g. 8000-10000 words), WJEC would then question whether learners succeeded to keep your project focused enough". As my project is currently slightly over 8000 words, I will aim to cut it down slightly. My tutor suggested placing some details about Atrial Fibrillation in the appendix if possible. I shall go through the essay and set a target of 7000 words, comfortably below the point where the WJEC may question the focus of my project. I plan to achieve this in the next two weeks if possible, so that I am free to focus on A-level studies when I return to college. I am very pleased with my feedback overall as it shows that my project is at a high standard and I will strive to cut down the word count and change my referencing to be Harvard referencing.	
	Learner signature: 	**Supervisor signature:**

EPF 3	EXTENDED PROJECT WRITTEN PROJECT OUTCOME	

This section should include:

Written Project Outcome (Dissertation, Field Investigation, etc.)

Note: Additional pages should be inserted as required to accommodate the Written Project Outcome.
The following headings are included as a guide only.

Project Outcome Notes

(minimum of 5000 words)

To what extent do the use of Artificial Intelligence systems in Medicine contribute to the socio-economic condition of society?

Abstract

Implementation of Artificial Intelligence systems in Medicine is limited but highly effective where utilised. Use of these systems in smart devices to detect atrial fibrillation, a common heart condition, is saving millions of dollars in health care expenditure and hundreds of lives. These traits are broadly applicable to all of the roughly 26 medical AI systems in use, with around half of these being used for image analysis, although the economic benefit and number of lives improved vary depending on the disease targeted. Saving or improving the quality of lives through effective diagnosis and treatment is enormously economically beneficial as it reduces healthcare expenditure, enables a person to work for longer and enables doctors to spend more time on complicated cases. The social benefits are obvious as saving lives and enhancing the quality of life is massively beneficial to the patient and those close to the patient. As a result of the large number of lives saved or improved, the socio-economic impact for implemented Artificial Intelligence systems is large per system although small overall due to the small number of systems currently in use. Research into AI in healthcare also has a positive current socio-economic impact as it has directly led to systems that exist today, although this impact is far smaller than that of implemented systems. Far more systems are being researched and many of them prove that AI can outperform experts, encouraging more investment and research into the field which will lead to large long-term socio-economic advances. However, current impact is small as the vast majority of these projects are in the research phase. The socio-economic impact is slightly blurred as there are hurdles and ethical issues to be overcome with research into medical AI, such as the morality of allowing companies access to sensitive health data, the problems that stem from using unrepresentative healthcare data when training a model and the question of legal responsibility if a computer makes a mistake. Despite all this, the overall current socio-economic impact of Artificial Intelligence systems in Medicine is positive, if limited by the small number of systems that are actually used.

Abbreviations

Abbreviation	Meaning
AI / ai	Artificial Intelligence.
FDA	Food and Drug Administration (referring to the Food and Drug Administration of the United States of America)
ML	Machine Learning (this refers to a subset of artificial intelligence where computers learn and adapt over time. A typical example of a structure used by machine learning techniques is a neural network)
MRI	Magnetic resonance imaging
CT	Computerised tomography
USA / US	The United States of America
NHS	National Health Service (referring to the National Health Service of the United Kingdom).
NLP	Natural language processing
AF	Atrial Fibrillation
DP	Decimal Place
UK	The United Kingdom of Great Britain and Northern Ireland
EU	European Union

Introduction

Artificial Intelligence is a cutting-edge technology at the forefront of research and one that is predicted to have massive socio-economic ramifications in the future. It is estimated that AI will lead to between $359.6 and $773.2 billion in growth over the next five years (Chen et al 2016), with an estimated economic impact of $15.2 trillion by 2030 (Gillham et al 2018). However, commercial adoption of Artificial Intelligence is yet to be widespread with there being a binary divide between industries that do and do not use it, with healthcare being a prominent early adopter of AI (McCauley 2016). Artificial Intelligence raises a whole host of ethical issues which have serious social implications (Bossmann 2016). This has led many to question whether the economic gains artificial intelligence facilitates are cancelled out by the societal drawbacks that come with it, such as the furthering of inequity and reduced accountability stemming from the uncertain legal status of AI systems. Conversely, one may argue that the AI instigates positive social change, with the technology boosting medical efficiency, cutting medical costs and providing more reliable healthcare.

In this paper, the current socio-economic impact of Artificial Intelligence systems in Medicine will be evaluated, which may be used by others to determine the suitability of widespread AI usage in Medicine.

Definitions

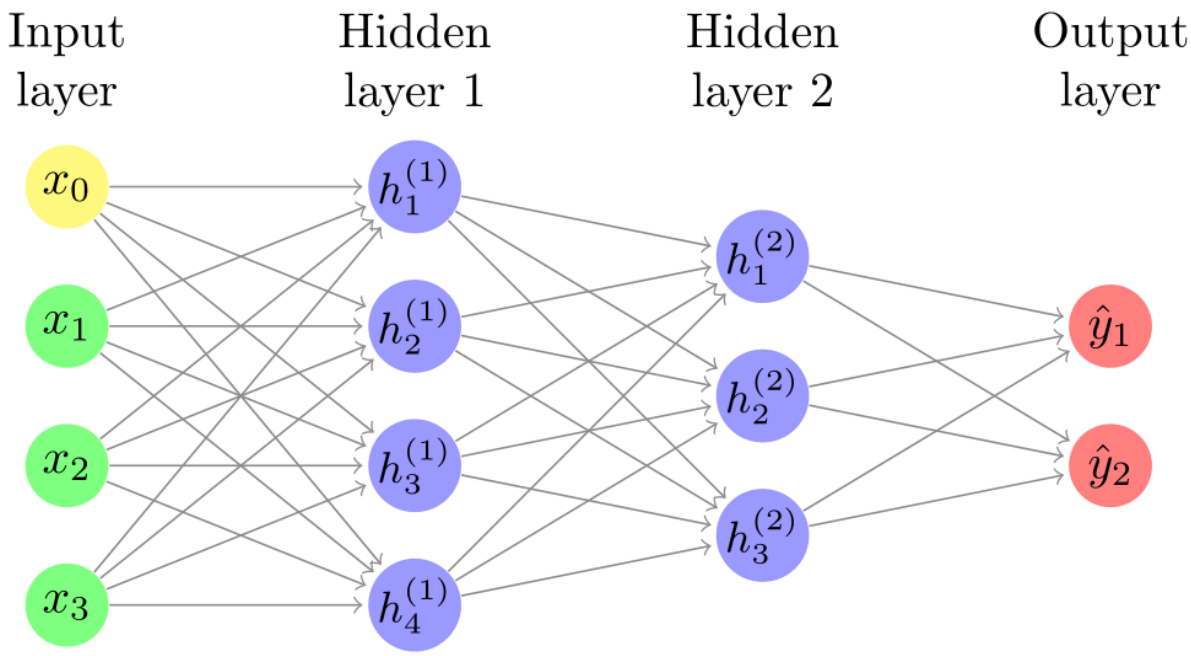
Artificial intelligence is defined as 'the study and development of computer systems that can copy intelligent human behaviour' (Oxford Learner's Dictionary). As such, when this dissertation refers to artificial intelligence systems, it is referring to computer systems that are can perform tasks comparably or better than humans. This encompasses machine learning systems but also covers more traditional computer programs such as rule-based systems (Tutorialspoint 2020) that are able to perform tasks to the aforementioned standard.

Medicine refers to the healthcare sector. Specifically, this essay defines medicine as:' the science or practice of the diagnosis, treatment, and prevention of disease' (Oxford English Dictionary).

This leads to the question that the dissertation is attempting to answer: "To what extent do the use of Artificial Intelligence systems in Medicine contribute to the socio-economic condition of society?".

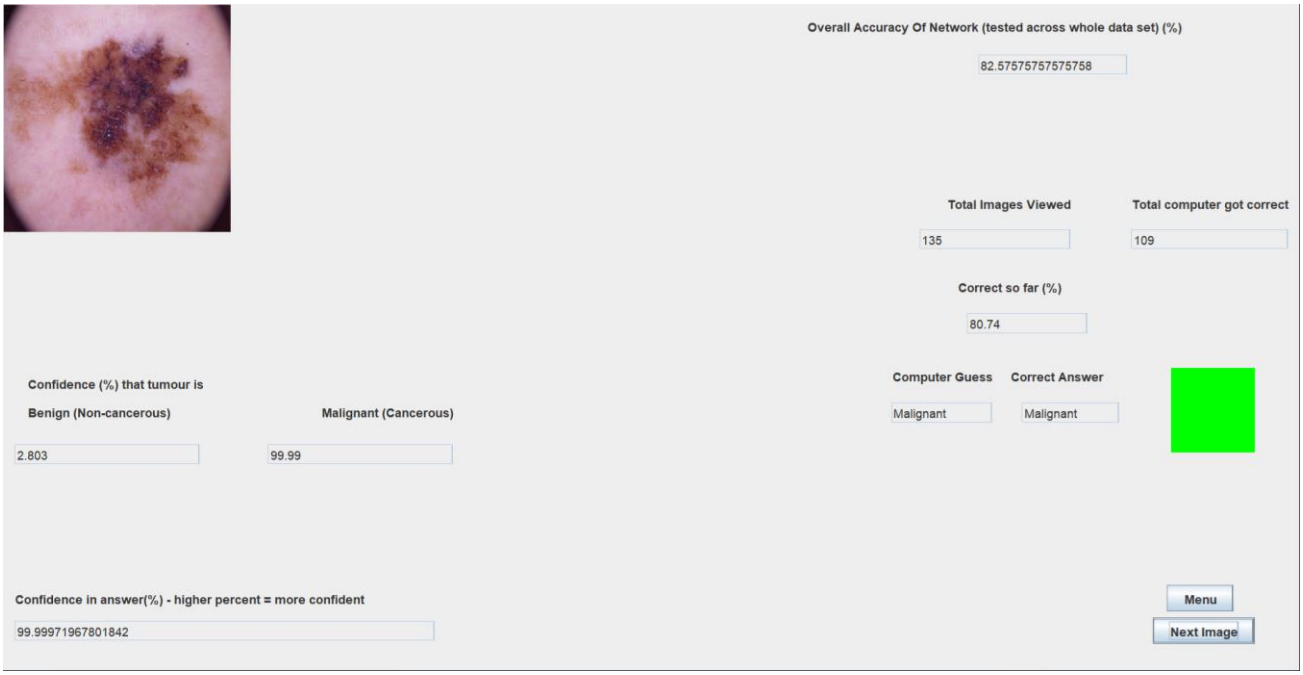
Overview of Artificial Intelligence

Artificial intelligence can take different forms, and can be as simple as people encoding knowledge into a computer (Tricentis) (e.g. if symptom x and y are present, probability of z disease is ø percent) or as complex as a self-learning system that mimics the structure of the brain and evolutionary mechanisms (Shiffman 2016). One highly potent Artificial Intelligence technique is known as deep learning which makes use of a structure known as a neural network (Thompson 2019). A neural network can be thought of as a highly complex non-linear, multi-variable function that consists of a large number of variables that are used to convert input data into some form of output. Through mathematical techniques such as gradient descent, networks can learn knowledge in a similar fashion to the brain and apply this to new situations (Hallström 2016). To achieve this, labelled data sets are often required (Castrounis 2020) (although there are also methods to train an AI without labelled data (Machado 2016) (Picasso 2020) (Silver et al 2018) (DeepMind 2020)) with the accuracy and size of the dataset impacting overall accuracy (Freethink 2018) (Google 2019). The ability of computers to learn in a humanlike fashion leads to a versatile range of applications, with deep learning systems being extremely competent with tasks such as image recognition (Sanderson 2017) and natural language processing (Jurafsky and Martin 2019) (Bailey 2014).



[Figure 1 - Neural Network architecture. Image from: https://tex.stackexchange.com/questions/153957/drawing-neural-network-with-tikz (accessed February 19th, 2020)]

[Figure 4 – Visualisation of a trained neural network recognising handwritten digits. This tool and network were coded by Philip Mortimer (the author of this dissertation). https://github.com/philipmortimer/MNIST-AI (accessed 13th July 2020).]



[Figure 8 – Visualisation of a neural network that analyses tumours to detect whether skin cancer is present. This network outperforms dermatologists, who achieve 65% – 80% accuracy (Argenziano and Soyer 2001).]

Prevalence of Artificial Intelligence Systems in Medicine

Artificial Intelligence in healthcare is a recent development and as such, there is lots of research being conducted in the field, but far fewer approved and implemented uses. In a 2016 survey (McCauley 2016), healthcare was found to be a leading industry in AI implementation, although its usage was still assessed to between exploratory and experimental. AI seems to hold incredible promise in the field, particularly in natural language processing (Vanian 2020) and image recognition (Singh 2018b) (Glocker 2017). (Jiang et al 2017) summarise a few instances where ML techniques have been applied in healthcare to great success. The use of AI to identify and aid treatment of strokes is highlighted. Similarly, (Mannini et al 2016) were able to accurately categorise different pathological gaits (stroke patients have identifiable gait patterns) 90.5% of the time. (Jiang et al 2017) however highlight that there are still large hurdles to overcome for successful medical AI implementation. For example, the FDA approved the first clinical machine learning software in 2017 (Marr 2017a), showing just how recent advances in the field are. This also highlights the low levels of AI use in healthcare. Despite this, there has been an increase in FDA approved AI applications. Figures 2 and 3 show that there were 14 approved uses in January 2019, but this had risen to 26 by April 2019. This rapid growth in implementation shows that the field is translating research into approved systems. Whilst this number is small, these systems have a clear socio-economic impact, particularly as many of these have to be proven to perform at least as well as humans. There is also a wealth of research in the field (Dankwa-Mullan et al 2019), which can also be evaluated as there are socio-economic implications stemming from such research projects, even if they are not as large as those from currently used systems.

Table 2 | FDA AI approvals are accelerating

Company	FDA Approval	Indication
Apple	September 2018	Atrial fibrillation detection
Aidoc	August 2018	CT brain bleed diagnosis
iCAD	August 2018	Breast density via mammography
Zebra Medical	July 2018	Coronary calcium scoring
Bay Labs	June 2018	Echocardiogram EF determination
Neural Analytics	May 2018	Device for paramedic stroke diagnosis
IDx	April 2018	Diabetic retinopathy diagnosis
Icometrix	April 2018	MRI brain interpretation
Imagen	March 2018	X-ray wrist fracture diagnosis
Viz.ai	February 2018	CT stroke diagnosis
Arterys	February 2018	Liver and lung cancer (MRI, CT) diagnosis
MaxQ-AI	January 2018	CT brain bleed diagnosis
Alivecor	November 2017	Atrial fibrillation detection via Apple Watch
Arterys	January 2017	MRI heart interpretation

[Figure 2. FDA AI approvals as of January 2019. https://twitter.com/EricTopol/status/1119683505603006469 (accessed on 8th June 2020)]

Quantib	Medical imaging (MRI)
CureMetrix	Medical imaging (Mammography)
BrainScope	Concussion Assessment (multi-modal)
Apple	Atrial fibrillation detection
Aidoc	Medical imaging (CT scan)
iCAD	Medical imaging (Mammography)
Zebra Medical	Medical imaging (CT scan)
Bay Labs	Medical imaging (echocardiogram)
Neural Analytics	Device for Paramedic stroke Diagnosis
IDx	Diabetic retinopathy diagnosis
Icometrix	Medical imaging (MRI)
Imagen	Medical imaging (X-ray)
Viz.ai	Medical imaging (CT scan)
Arterys	Medical imaging (MRI and CT)
MaxQ-AI	Medical imaging (CT)
Alivecor	Atrial fibrillation detection
DreaMed	Diabetes treatment decision
Arterys	Medical imaging (MRI)
Empatica	Warning of seizure risk
Subtle Medical	Medical imaging
Cognoa	Autism diagnosis
Healthy.io	Urinary tract infection diagnosis
Excel Medical	Remote monitoring
FibriCheck	Atrial fibrillation detection
ScreenPoint Medical	Medical imaging (Mammography)
SyncThink	Eye movement disorders

[Figure 3. FDA AI approvals as of April 20th, 2019. https://twitter.com/EricTopol/status/1119683505603006469 (accessed on 8th June 2020)]

Socio-economic Impact of Artificial Intelligence Systems in Medicine

As previously mentioned, AI systems in healthcare can be broken down into two categories: currently implemented and currently being researched. The vast majority of systems are in the latter category as large hurdles still remain for wide-spread implementation (Faggella 2019) (DW Documentary 2019) (World Medical Innovation Forum 2019)).

Many industry stakeholders are hesitant to invest as they feel that the financial benefits of the technology are unproven (Faggella 2019), which is argued to lead to a lack of investment which in turn means that there is little evidence to show AI's financial benefits. Fortunately, it appears that the industry is becoming more aware of AI's capabilities as numerous studies prove the potential for AI to cut costs and make treatment more effective. This idea that research leads to investment shows that researching AI applications in Medicine has a socio-economic impact as some of the systems being researched will make it to market, and others will encourage further investment in the field.

Research into Artificial Intelligence Systems that could be used in Healthcare

Deep learning systems are highly adept at analysing large amounts of data, particularly labelled data. As such, one of the most common applications of AI is image recognition (Glocker 2017) (Google Developers 2018), with advanced techniques enabling computers to recognise images correctly as often as 99.77% of the time (Cireşan, Meier and Schmidhuber 2012). The healthcare sector makes use of a wide range of imaging techniques such as x-ray scans, MRI scans and CT scans which are invaluable in diagnosis and disease prevention. NHS England performed 40.2 million imaging tests over a twelve-month period spanning from July 2015 to June 2016. However, response time was not flawless, with patients who received an MRI scan waiting an average of three days for results. Furthermore, time between request for a scan and scan being carried out was highly variable ranging from the same day to a wait of 21 days (Operational Information for Commissioning 2016). Software that is able to automate or speed up the process of scan analysis would reduce waiting times and time for reports to be released (Lungren 2018). As such, AI holds great promise in freeing up doctors to perform other tasks as well as improving diagnosis accuracy.

One recent breakthrough is a breast cancer diagnosis Artificial Intelligence system that analyses mammograms. The computer was trained on scans from nearly 29,000 women (Walsh 2020) and was found to outperform British radiologists, with a 1.2 percent reduction in false positives and a 2.7 percent reduction in false negatives (McKinney et al 2020). Furthermore, the system was able to perform as effectively as two radiologists working together. Currently, a mammogram is analysed by two radiologists and if disagreement exists, a third radiologist is consulted (Walsh 2020). Reading scans is 'time-consuming work' (Walsh 2020) and one can expect to wait up to two weeks to receive screening results (NHS 2018). The system could be used as an alternative to a second radiologist which would speed up the processing of results (which is important as early identification of breast cancer dramatically increases survival chances (Cancer Research UK 2019) and would help address the shortage of radiologists which is estimated to be over 1000 (Walsh 2020). In this instance, there is large economic potential as it speeds up vital work and ultimately makes radiologists more cost-effective. Increased diagnosis accuracy has massive economic value as increased survival chances allow more people to work (not to mention the massive social benefit that comes with saving a life). However, this paper is considering the current socio-economic impact which is more limited. Short term economic impact is arguably negative as research of this manner comes at a price. However, research is an investment and given the extremely promising results, the long term-economic impact of this will be highly positive as it will improve diagnosis accuracy, leading to fewer deaths. Computers have the advantage of performing consistently and not getting tired and thus can provide faster and more consistent analysis (The Economist 2019). Therefore, even if no changes were made to the system apart from using the computer in addition to the radiologists, accuracy and confidence in results could be increased. The AI would also enable doctors to prioritise more urgent mammograms. Therefore, the overall economic impact is positive but limited as it will encourage more research and eventually lead to better treatment of disease,

albeit at considerable current cost. There are also social considerations, not the least the implications of granting access to 29,000 scans. Naturally, some feel uncomfortable at the prospect of handing over intimate data and argue that patients have a right for sensitive data to remain private. However, I would argue that appropriate safeguarding measures have been taken as the data has been anonymised (Walsh 2020). The precedent of granting access to sensitive data for research to third party organisations is nonetheless one that many will be uncomfortable with, particularly as they may have no say in the matter. Despite this, the societal benefits of improved breast cancer screening drastically outweigh such risks which can be managed by steps such as anonymisation. Studies like these provide a great social benefit as they encourage more research, which leads to improved treatment. Therefore, I conclude that research into AI does in fact have a net positive impact as it facilitates improved healthcare, although there are important negative aspects that need to be considered.

This study into breast cancer diagnosis is typical of a large range of studies which use AI for scan analysis (Hicken, Bowen and Woods 2020). Imaging AI research that has comparable results includes detecting liver disease (Zhou et al 2019), muscular sclerosis treatment (Kanber et al 2019), and aiding treatment of cardiovascular disease (Siegersma et al 2019). As much of the research into medical AI is of similar nature (namely imaging enhancement), one can conclude that the socio-economic implications of research into radiology are broadly applicable to wider research. The $500 million invested in Medical Imaging AI companies across a six-month period in 2018 (Harris 2018) demonstrates the high research funding levels. This naturally has negative short-term economic implications as large amounts of money are being invested into technology which is unlikely to return this investment over a short period of time. The long-term economic impact is far less clear as the technology has massive promise, however there are still significant hurdles to overcome for wide-spread implementation. Investment in AI research undoubtedly makes its implementation in Medicine a more realistic prospect in the future and will help to overcome the challenges it faces. If AI can overcome certain hurdles, the economic impact will ultimately be positive as it will enhance medical practice. A review of 69 studies published in the Lancelet found that deep learning models were able to perform at a similar level to healthcare professionals (Liu et al 2019), showing that if these hurdles can be overcome, the potential socio-economic rewards are large and obtainable in the foreseeable future.

Problems with Implementation of Artificial Intelligence Systems in Healthcare

AI systems face enormous hurdles before they can become widespread in healthcare (Panch, Mattie and Celi 2019). All systems need to be approved before use by agencies like the FDA, who set high approval standards.

There are difficult legal issues to be evaluated when using AI (Harvard Medical School 2018). Medical error is a serious issue, with a John Hopkins University study assessing medical error to be the third highest cause of death in the US in 2016, with over 250,000 annual US deaths attributed to it (Makary and Daniel 2016). This leads to a large number of medical malpractice cases (Rosenbaum & Associates 2020). However, who is legally responsible if a computer system makes a poor decision? This is a complex and somewhat unclear legal question, although AI systems used to enhance the strength of a doctor's decision as opposed to replacing it are believed to be acceptable. The FDA appears to be accepting of systems used for a "non-serious situation" (FDA 2019) and is open to AI use throughout healthcare, but the truth is that most AI systems are used to support Doctors, not replace them. If the system makes a mistake that results in the death of a patient, who should be held accountable? One of AI's flaws, much like humans, is that it is almost certain to act imperfectly. It may even outperform humans, but it is much harder to hold a computer accountable for malpractice. Currently, legislation and guidance are unclear as to who may be accountable and varies from country to country. However, AI is not yet at a level where this is much of a problem as it is typically only used to support medical decisions.

(Huss 2018) points out that ML AI is limited in its ability to aid doctors as self-learning models can often be thought of as a black box. This is because the model is attempting to extract meaningful information from a dataset to produce an output (e.g. the probability that a patient has breast cancer). However, models often have millions of variables and it is normally impossible to determine what these models are looking for. Thus, AI lacks the expressiveness and ability to justify a decision which is of great importance to doctors.

Self-learning models are limited by the amount of and quality of data available to them and as such may be deeply flawed if the dataset trained on does not include a wide enough range of information. This is a substantial flaw and has serious social implications as it may mean that members of the public with a rarer instance of a disease (that the AI may not have encountered in training) will be adversely impacted. Furthermore, the opacity of such systems makes it harder for doctors to trust them, particularly when a doctor disagrees with the computer (Harvard Medical School 2018). It is important to note that the article by Huss has a potential conflict of interest, as Huss is developing a platform to address some of the issues he describes in the article (although this would of course make him knowledgeable on the subject). Despite this, the issues described are a common problem with AI; debate around the usability of black-box models is widespread. A piece in the British Medical Journal (Watson et al 2019) concludes that AI has the ability to radically improve diagnosis, but that the lack of clarity surrounding its decision-making process is a large weakness which limits its trustworthiness to doctors. Anna Goldberg, a genetic scientist, argues that the priority is to build the "best system" and then develop tools that interpret the AI (Bender 2019), although few of these tools have been developed. However, Katherine Andriole points out that machine learning models are predominantly black boxes, but that use of technology such as a saliency map (which shows which features a model is analysing (Lungren 2018)) and analysis of networks can make them more understandable (World Medical Innovation Forum 2019)). However, Andriole goes to on to stress that the black box nature is still a primarily unsolved problem, particularly as the FDA says this issue still needs to be overcome (World Medical Innovation Forum 2019). Given all this, I feel that if one can develop an AI of sufficient accuracy and convey this accuracy to physicians, they should be confident in the tool even if they do not fully understand how it operates. However, the black box nature of AI certainly has an overall negative social impact as it leads to distrust and makes it much harder to detect AI systems that may be failing to properly consider important factors. But this on it is own is not a real hurdle to implementation, particularly when considering the accuracy of various healthcare research projects (Liu et al 2019) and the fact that some black box systems have already been implemented into healthcare. Furthermore, AI is far from the only black box in healthcare with many tests displaying similar if not lower accuracy rates such as the RT-PCR test for COVID-19 (which has a believed false negative rate of between 2 and 29% (Arevalo-Rodriguez et al 2020) (Watson, Whiting and Brush 2020), although it must be noted that the study has not been peer reviewed and that this figure is still far from certain).

Whilst there are hurdles to be overcome as medical AI transitions from research to actual implementation, these issues can certainly be solved. This is proven by the fact that numerous AI applications have already achieved FDA approval, including the first medical imaging AI that detects lesions (Carfagno 2019). This along with statements by the FDA (Gottlieb 2019) shows a willingness to work with researchers to make the transition from research to approval, although the lack of explicit guidance is still problematic. Therefore, I conclude that whilst challenges such as legal accountability of AI are still prevalent issues, they do not significantly prevent strong deep learning models transitioning from development to use (as evidenced by the approval of the lesion detection AI (Carfagno 2019)). This makes the socio-economic impact of AI research in healthcare far more positive as it shows that research can directly lead to use even if the process may be arduous, slightly ambiguous, and lacking in precedent. Thus, research can in many cases simply be viewed as a foundation that establishes the viability of a system and given the high viability of many systems (Liu et al 2019), it can be concluded that research leads to implemented systems, which have a positive socio-economic impact.

Artificial Intelligence Systems currently used in Medicine that Perform Specialist Tasks

Atrial fibrillation occurs when 'electrical impulses fire off from different places in the top chambers of the heart (the atria) in a disorganised way' (British Heart Foundation 2019). This results in an irregular heartbeat and can leave suffers feeling faint, although many are asymptomatic (British Heart Foundation 2019) (Arrhythmia Alliance 2020). However, atrial fibrillation detection is difficult, leaving an estimated 13.1% of atrial fibrillation cases undetected (Turakhia et al 2018), which is significant given the prevalence of the condition which is thought to be present in 5 million US citizens (Turakhia et al 2018). This means that there are an estimated 700,000 people in the USA who are unaware that they have the condition (Turakhia et al 2018), which is massively important given that people with untreated AF are five times more at risk of a

stroke (Stroke Association 2017) than the average population and that 31.2% of strokes are associated with AF (although this number is variable as it is based on a sample size of 568 stroke patients) (Hannon et al 2019). The issue has massive economic ramifications as undiagnosed AF in the USA is estimated to cost $3.1 billion (Turakhia et al 2015), with a study into the issue concluding 'strategies to identify and treat patients with undiagnosed AF could lead to sizable reductions in stroke sequelae and associated costs' (Turakhia et al 2015). Given this, it is economically and medically advantageous to detect AF in cases where people may be unaware that they suffer from the condition, as through diagnosis and subsequent treatment, stroke risk can be reduced by 64% (Hart, Pearce and Aguilar 2007). However, it is difficult to devise a strategy to identify patients with undiagnosed AF even through measures such as randomised check-ups (which in themselves would be cost ineffective) as they would fail to catch many cases as many sufferers have "AF episodes that come and go" (known as paroxysmal AF) (Tidy and Bonsall 2017).

It is estimated that over 70 million Apple Smart Watches have been sold since its release in 2015, with this number anticipated to rise (Canalys 2020) (Chandrasekhar 2019). Included in the device is a heart rate monitor which has the accuracy of a clinical device (El-Amrawy and Nounou 2015). Given this much more frequent and highly accurate access to a person's heartbeat, Apple looked into the possibility of using this to detect AF. Through the training of a deep neural network using data provided by 9750 participants, an AI was developed that had a true positive rate of 98.04% and a true negative rate of 90.02% (Tison et al 2018) (Singh 2018a). Apple obtained FDA approval and the Apple Watch now has the ability to detect AF in certain countries (Apple 2020) (Fox 2018) [Figure 2] [Figure 3]. This technology is not unique as both FibriCheck (Loon 2018) [Figure 3] and Alivecor (Capritto 2019) [Figure 2] [Figure 3] also have FDA approved AF detection systems. FibriCheck's software is different as it detects AF through a smartphone and without any external accessories (although this does come with the downside that the patient has to manually record their heart rate, unlike Apple's which take automatic readings). Given the large market of smartphones, with roughly 1.5 billion sales in 2019 (Gartner 2020), and smart watches (Canalys 2020) such as the Apple Watch, there is undoubtedly the potential for large scale asymptomatic AF detection.

In order to determine the impact of AF detection systems, this paper will analyse The Apple Heart Study. The study was carried out across 419,093 participants who had not been diagnosed with AF and was designed to determine the proportion of patients who received irregular pulse notifications that were subsequently diagnosed with AF (Turakhia et al 2019). The large sample size means there can be a high confidence in the results obtained, although the study design is limited by a few factors (Husten 2019). The study failed to meet its target of 500,000 participants which is of little consequence as the sample size is still large. It also failed to meet its target of 75,000 participants over the age of 65 which is of greater consequence as AF is more prevalent in the elderly. However, one could argue that this may be a reflection of the younger demographic of the Apple Watch and highlights more of a flaw with the use of the technology as a means of diagnosing AF as opposed to with the study itself. The study's accuracy is limited by its reliance on the self-reporting of patients (American College of Cardiology 2019) which would reduce confidence somewhat, however this too is likely to be negated by the large sample size. As one had to register for the study digitally, one could argue that the demographic may be skewed slightly towards those who are more technologically competent.

[Figure 6. An example of the health app tracking the heart. https://www.apple.com/newsroom/2018/12/ecg-app-and-irregular-heart-rhythm-notification-available-today-on-apple-watch/ (accessed on 14th July 2020).]

[Figure 7. An example of an irregular pulse notification. https://www.apple.com/newsroom/2018/12/ecg-app-and-irregular-heart-rhythm-notification-available-today-on-apple-watch/ (accessed on 14th July 2020).]

Overall, 0.52% of participants received irregular pulse notifications, with the pulse detection algorithm having a 71% positive predictive value. Of the people who received an irregular pulse notification and followed up, only 34% were found to have atrial fibrillation. The study points out that this does not mean that only 34% had AF, but that many of them may have had paroxysmal AF that was not present during the follow up. Only 0.16% percent of participants under the age of 40 received a notification, whilst just over 3% of participants over the age of 65 received one, highlighting the greater prevalence of AF amongst the elderly. In the study, 0.1768% of participants were found to have AF, which is roughly 77% of the number of expected cases. This should serve as an upper estimate for the capability of the watch as its accuracy is negated by lack of trust in the technology which may lead some to ignore notifications. This issue can be circumvented by education, but it is important to note given that only 57% of notification receivers sought healthcare. (Stanford University 2019) (American College of Cardiology 2019) (American Heart Association 2019) [Figure 5]

Given undiagnosed AF's cost of $3.1 billion (Turakhia et al 2015), if the Apple Watch has the potential to identify 77% of these cases, it has the potential to reduce healthcare expenditure by about $2.4 billion in the US. If one applies this to the rest of the world (which will lead to a rough estimate), one can conclude that the Apple Watch has the potential to save $55.9 billion (which is unrealistic as it assumes that every person on Earth wears a watch). Of course, the actually impact of the watch is significantly lower due to the younger demographic, lack of trust in the in the technology as well as its £300 price. However, if we take the estimate of 70 million (Canalys 2020) (Chandrasekhar 2019) Apple Watch owners and combine it with the result of the study, the Apple Watch would save $548 million (although not all 70 million are active users of the watch). And this number would only grow with increased education, sales of the Apple Watch (as each sale, on average, saves $7.8) and a more diverse user base. [Figure 5]

Percent of population with undiagnosed AF in 2009 in USA = number with people with undiagnosed AF in USA / population of USA in 2009 = 700,000 (Turakhia et al 2018) / 306,307,565 (Population Pyramid) = 0.228528373% (rounded to 9 DP)
Percent of Apple Heart Study with undiagnosed AF that was detected = percent of irregular pulse notifications * percent of AF cases diagnosed following irregular pulse notifications = 0.52% (American Heart Association 2019) * 0.34% (American Heart Association 2019) = 0.1768%
Percent of cases that Heart Study identified = Percent of Apple Heart Study with undiagnosed AF that was detected / Percent of population with undiagnosed AF in 2009 in USA = 0.1768 / ((700,000 (Turakhia et al 2018)) / 306,307,565 (Population Pyramid)) = 77.3645393% (7 DP)
Potential (i.e. maximum) Economic Burden Reduction of Apple Watch through AF diagnosis in US (assuming all US citizens have an apple watch, which they do not) = economic impact of undiagnosed AF in US * Percent of cases that Heart Study identified = 3.1*10^9 (Turakhia et al 2015)* (0.1768 / ((700,000 (Turakhia et al 2018) * 100) / 306,307,565 (Population Pyramid))) = $2,398,300,718 (Note: this is a lower estimate as they 3.1 billion has not been adjusted for inflation from 2015)
Potential (i.e. maximum) Economic Burden Reduction of Apple Watch through AF diagnosis in the World (assuming all citizens have an apple watch, which they do not) = Potential (i.e. maximum) Economic Burden Reduction of Apple Watch through AF diagnosis in US (assuming all US citizens have an apple watch, which they do not) * (population of world / population of USA) = 2,398,300,718 * (7,763,035,303 (Countrymeters 2020a) / 332,865,306 (Countrymeters 2020b)) = $55,932,813,677 (rounded to nearest whole number)
Current economic savings per Apple Watch due to AF diagnosis = Percent of Apple Heart Study with undiagnosed AF that was detected * (economic impact of undiagnosed AF in US / number of people with undiagnosed AF in US) = 0.001768 * ((3.1*10^9 (Turakhia et al 2015))/700,000 (Turakhia et al 2018))= $7.82971429 (rounded to 8 DP)
Current economic savings caused by Apple Watch's ability to diagnose AF (assuming all people who have ever purchased an Apple Watch still wear it regularly) = Current economic savings per Apple Watch due to AF diagnosis * estimated number of apple watch sales = (0.001768 * ((3.1*10^9 (Turakhia et al 2015))/700,000 (Turakhia et al 2018))) * 70,000,000 (Canalys 2020) (Chandrasekhar 2019) = $548,080,000

[Figure 5. Mathematics performed by author of the dissertation (Philip Mortimer). Last updated: 6th July 2020.]

Clearly, the current economic impact of the Apple Watch is large although not as large as $548 million as only around 57% of users seek care following a notification and as the Apple Watch AF detection software is region specific. It is also limited by the fact that this feature needs to be manually turned on by the user. However, all of these issues can be counteracted through education and as such are not serious hurdles in the long term. The economic impact extends far beyond the Apple Watch as this technology has the potential to be used by all wearables as well as mobile phones (although mobile phone AF detection is less advanced as the device is not taking continuous measurements), covering about half of the world (O'Dea 2020). The social impact is large as reduction in healthcare expenditure is advantageous as is the saving of lives. The Apple Watch will save lives as AF treatment is believed to reduce stroke risk by between a half and two-thirds (NINDS 2019), which is important given that 28% of stroke victims die within a month of the stroke, increasing to 41% after a year (Stroke Belt 2019). As a result of all this, AI is saving many hundreds of lives and millions of dollars through AF diagnosis. As clinical approvals and adoption of smart technology increase, the number of lives and economic value provided by the software will increase. Many point out that pulse detection and analysis algorithms can be extended to a range of cardiovascular diseases. This technology is already used in fitness tracking software which improves general wellbeing as it inspires and enables greater fitness levels.

A large amount of other approved Artificial Intelligence systems in healthcare revolve around medical imaging with 13 out of the 26 FDA approvals in Figure 3 being used for imaging. At the moment, most of these imaging tools analyse images in a similar manner to the aforementioned mammography AI with the key difference being that the systems are primarily used in order to strengthen the decision of a doctor as well as prioritise human analysis of those that are more likely to be at immediate risk. As such, they do increase the accuracy of medical advice and enable faster treatment for those who require it. There are far fewer approved diagnostic imaging devices, however one such approval is for the diagnosis of diabetic retinopathy which the FDA has approved to be utilised without a specialist (Brooks 2018), with the system

achieving about 90% accuracy (Abràmoff 2018). This has a large impact as over 24,000 cases of blindness each year in the USA are attributed to the disease (with blindness costing $5.5 billion in annual medical expenses in the US and 209,000 quality-adjusted life years in the USA) (Frick 2007). Accurate AI screening empowers doctors to reduce the number of blindness cases caused by diabetic retinopathy, which would be beneficial as blind people often struggle to contribute economically and socially as blindness is a life changing impairment. However, if we look at AI in medicine as a whole, we see that diagnosis AI is rare although massively useful in the fields it is used in.

Conclusion

Medical Artificial intelligence has massive potential as deep learning models are suited for medical tasks such as image analysis. This is reflected in the large amount of research in the field, with a vast range of software that performs comparably or favourably against doctors. Whilst AI's promise is clear, most research has yet to be implemented for numerous reasons. As the field is new, there is no precedent as to whether software creators could be held accountable for incorrect decisions made by AI. The FDA and other bodies appear to be willing to provide guidance and approve AI in the field, however companies are hesitant to invest in a new field which still needs these questions answered. In order to assess the overall current socio-economic contribution of medicinal Artificial Intelligence, one must analyse both currently implemented AI and research in the area.

Research into AI in healthcare is wide-ranging and has proven AI's ability to perform as competently as doctors without drawbacks such as getting tired. Much of this research will undoubtedly be implemented in the next few decades, leading to massive socio-economic gains. One could therefore argue that research facilitates AI implementation and is required in order to implement these lifesaving algorithms. For example, the aforementioned breast cancer model that outperforms physicians has the potential to save countless lives. Such technology can only be approved through research that demonstrates its ability. One can imagine the benefits of research to be similar to those of investing in the development of a vaccine: in the immediate short term it may be expensive, but in the long term it has the potential to save countless lives. Research also proves the potential of AI, encouraging others to invest in the technology and ultimately leading to a better healthcare system. All of the currently implemented AI systems were made possible through research, which shows that it does have a current socio-economic impact, although this is limited as there are few approved uses. There are also detrimental social considerations as advanced AI models require large amounts of training data. This raises some privacy concerns as sensitive data such as mammograms are often divulged to third party companies such as Google without the patient's knowledge, although mitigation strategies such as data anonymisation have quelled these fears somewhat. There is also a fear that patients who display atypical symptoms of a certain disease may be misdiagnosed by systems as the black-box nature of AI makes it nearly impossible to discern what an AI actually uses to predict whether a disease is present. For example, Amazon once built an AI to filter through resumes to determine strong applicants and was trained using Amazon's employment records. As these records were of predominantly male employees, the AI perpetuated this bias and concluded that female applicants were inferior to male applicants (Dastin 2018). There are fears that this may be seen in medical AI if designers are not careful as it could interpret, for example, that somebody may be more likely to have a certain illness because of their race. For example, if a disproportionately low number of patients from a certain ethnicity are represented in the training data this bias may carry across to implementation (Harvard Medical School 2018) (Glocker 2017). This may further the racial inequity present in healthcare (Williams and Lavizzo-Mourey 2016) (Booth and Barr 2020) (Egede 2006). However, there is little evidence to show that these fears are warranted, partially because few algorithms have been implemented and tested on such a large scale. This is an issue that can be countered by limiting irrelevant data and ensuring sample data is large and representative. Given all these considerations, this paper concludes that research into medical AI is massively advantageous in the long term. However, its current socio-economic impact is more limited. This paper argues that the current economic impact is limited as research is very expensive, however it is argued that the impact is still positive as it has led to a very small number of implementations, but that these implementations have a

large positive current economic impact. The societal impact is more mixed as research has led to systems that do save many lives and enhance the quality of life for many people. However, ethical concerns remain about who is legally responsibility for the failure of medical AI systems. There are also concerns about the morality of companies accessing sensitive healthcare data as well as the quality of such data potentially leading to the furthering of healthcare inequity due to factors such as race. One could also counterpoint this by saying that research will possibly save thousands of lives, which is massively socially beneficial. It is also important to note that many hurdles to widespread implementation can be overcome through legislation, governmental guidance on development of AI systems and careful software design. The long-term social impact is highly positive, but the current social impact is slightly negative because of these concerns, although it must be acknowledged that the research has led to a small number of systems that already make a large positive social difference.

Currently implemented AI systems in healthcare have a much larger overall impact. For example, Apple Watch's atrial fibrillation detection feature saves an average of $7.8 per user in healthcare expenditure, saving millions over the watch's entire user base. AF Diagnosis leads to fewer strokes, therefore saving and improving the quality of lives. Similar algorithms are used by other companies and allow for constant AF monitoring through smartwatches and phones. One could argue that it could further the health divide between the rich and poor, although this isn't really a drawback as the overall quality of healthcare is improved, it is just, unfortunately, less accessible to those less well off. There are a few approved diagnostic AI systems with humanlike accuracy that facilitate more effective screening for diseases like diabetic retinopathy, as experts are not needed to analyse every scan. This means that a larger group of people who are at risk can be scanned and thus more cases are detected. Around half of all FDA approved AI is used in imaging and is often used to strengthen a doctor's decision or to screen a wider pool of people more quickly, with the doctor then being able to target those who need professional analysis first. Each of the currently implemented systems has an incredible economic impact as they are highly effective in increasing quality of diagnosis and healthcare. Enhanced diagnosis and treatment save lives and enhance the quality of life, often reducing medical expenditure and allowing more people to work and thus contribute economically. There are obvious and substantial social benefits in enhancing and saving thousands of lives which appear to come with little drawback apart from perhaps a lack of trust in these systems as well as the black-box nature of these systems potentially leading to serious undetected mistakes. The current impact is primarily limited by the fact that there are so few systems implemented (with around 26 FDA approved systems), although this number appears to be growing rapidly [Figure 2] [Figure 3]. This suggests that AI adoption will be widespread in healthcare in the coming decades. At the moment, the socio-economic impact is large in medical sectors that it is used in as it saves many millions of dollars and saves and improves the quality of thousands of lives. Its use is small relative to the size of the medical industry, but in the small number of places where it is used, it is effective and makes an enormously positive socio-economic impact.

One can conclude that AI in healthcare has a sizeable and substantially positive socio-economic impact although it is severely limited by its lack of widespread implementation and slightly limited by societal implications regarding the dependency on large amounts of sensitive data. The economic impact of AI in healthcare is overwhelmingly positive as it reduces healthcare expenditure and saves lives, which enables more people to contribute to the economic wellbeing of society. Although investment into research is expensive, this expenditure will be paid back many times over in the long term and has already been paid back with algorithms such as AF detection which save millions of dollars annually. Economic and social benefit are intrinsically linked as lifesaving and diagnosis of disease lead to positive societal and economic gains. As such, research and implementation are socially beneficial as they save and enhance the quality of lives. As a result of all this, this paper concludes that artificial intelligence systems in medicine have a large positive social and economic impact, even if this is substantially limited by the fact that only a very small number of Artificial Intelligence systems are currently used in Medicine. However, this just shows precisely how positive the socio-economic impact of each Artificial Intelligence system in Medicine really is.

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Source Evaluation / Literature Review

My source evaluation / literature review will consist of the source reference, a summary of what the source says, and a discussion on its reliability. Relevant links between sources and between sources and the project will be discussed where appropriate. As there is no direct research that determines the overall current socio-economic impact of artificial intelligence in medicine, there is little literature about the subject that currently exists. However, there is a lot of literature covering various facets of AI in medicine such as AI in mammography, primarily research into developing AI systems for a particular field. As such, the sources used in the dissertation serve as a literature review as they encompass relevant research into the field. As such my source evaluation will serve as an evaluation and a literature review. However, it is important to note that this is not considered a part of the dissertation but rather as a part of the wider process involved with the extended project qualification.

(Abràmoff 2018). This study analyses the effectiveness of IDx-DR (talked about in (Brooks 2018)) to detect mild diabetic retinopathy. Across a modest sample of 900 people, the system achieved a roughly 90% accuracy and these findings are partially responsible for the FDA approval of the system according to the paper. The peer-reviewed entry is clearly accurate as the FDA had to accept the results of the findings in

order to approve the system. However, the confidence in the data is slightly limited by the small sample size but one can safely conclude that 900 people is a large enough sample to show that the system is effective. This ability to accurately diagnose the condition "without the need for a clinician to also interpret the image or results" is a breakthrough in medicinal AI and shows that AI is suitable for replacement of human doctors even if experts are still required to assess more serious cases. This does beg the question as to a possible negative social impact of leading to the redundancy of medical professionals in some fields which leads to unemployment and possibly a stagnation in research. Although, these are arguably outweighed by the ability to screen more people and high levels of accuracy provided by such a system.

(American College of Cardiology 2019). This article summarises the results of the Apple Heart study and includes an interview with one of the researchers involved in the trial. The contents of the article are accurate as the results have been widely reported. The piece highlights that only 57% percent of participants who received a notification sought healthcare, perhaps showing a lack of trust in the capabilities of the Watch and are certainly a flaw of the trial in the sense that it may have had a large impact on the accuracy of the watch if those people also sought healthcare. However, the results were promising with the Apple Watch showing a high true positive rate although some were surprised by the low number of notifications given out. The source is clearly reliable and also highly relevant to this dissertation as these numbers show the strength of the watch and can be used to obtain rough estimates for the economic impact of AF detection software.

(American Heart Association 2019). This article, similar to (Stanford University 2019) and (American College of Cardiology 2019), summarises the results of the Apple Hearts Study and features an interview with the Apple Heart Study Primary Investigator (an academic working at Stanford University). The information is clearly accurate as it comes from reliable sources, including one of the members who conducted the study. This piece is important as it shows that the Apple Watch is effective at diagnosing AF which is important as it is a feature can be used without the user having to manually take readings. As such, it has massive potential as one only has to wear the watch in order to be screened for the condition. The ability of AI systems to screen for a range of diseases without the participant actively needing to do anything is pivotal as it enables a large group of people to be screened for a wide range of diseases.

(Apple 2018). This news article by Apple states that their atrial fibrillation detection AI used in the Apple Watch has been approved by the FDA with a "De Novo classification", meaning that the system is available over the counter. The article is biased as it is written by Apple with the intention to paint them in a positive light, but the article is relevant to the dissertation only so far as to confirm that the feature has been proved by the FDA (which is also independently verifiable). This shows that the FDA views the software to be safe and appropriate for use, demonstrating confidence in its accuracy. It also is important as it shows the ability of AI systems to receive governmental certification and essentially shows that the results from the Apple Heart Study can be used to estimate the potential economic impact of the AF detection in the smart watch.

(Apple 2020). This piece on the support section of Apple's website talks about the irregular pulse notification on Apple Watches that can be enabled. The support piece highlights that the feature is not supported in all countries but is in some. This source is valid as it is designed to inform an Apple Watch user and comes from the company who would know the finer details about the watch.

(Arevalo-Rodriguez et al 2020). This piece reviews existing work to attempt to calculate the false negative rate for a commonly used test for COVID-19. The piece concludes that there is an up to 29 percent false negative rate for the RT-PCR COIVD-19 test. However, this piece is highly unreliable as it is published very early on into the lifespan of the COVID-19 pandemic and is using data from other samples that will be limited by errors that are not the fault of the test such as human error and mixing up of samples. Furthermore, this work has not been peer reviewed and the publisher even stresses that this number should not viewed as a fact and that the evidence is severely limited for a range of reasons. As such, the source lacks validity and confidence in the results. However, it is of some use as it shows that tests, which are similar to an AI in their black box nature (i.e. they often return yes or no) are also flawed and are still widely used for obvious reasons. Admittedly, this comparison is not entirely fair as the process behind the test is

understood and often the accuracy of the test is also understood (although the accuracy of the COVID-19 test is not completely agreed upon).

(Argenziano and Soyer 2001). This piece is published in the Lancelet, a highly reputable medical journal that peer-review all published articles to a very high standard. This paper focuses on techniques used for enhancing the accuracy of melanoma diagnosis. The piece is referenced by a large number of highly reliable sources and all of the contents are researched and verified to the highest standards. Given this, I have accepted the source to be valid. The source is important as it states that dermatologists achieve between 65% - 80% accuracy at melanoma diagnosis, a relevant figure as state-of-the-art AI systems perform at a higher level. Hence, the piece is clearly, reliable, relevant and valid.

(Arrhythmia Alliance 2020). Similar to (British Heart Foundation 2019), this piece also talks in detail about many aspects of AF and provides advice for patients including about treatment methods. The Arrythmia Alliance's goals are to "to improve the diagnosis, treatment and quality of life for all those affected by arrhythmias" (such as AF) and as such are highly likely to be informative and fair, something which is backed up by the fact that their information matches that of (British Heart Foundation 2019).

(Bailey 2014). This 2015 newspaper article talks about tech companies investing into Artificial Intelligence, particularly in its advanced natural language processing capabilities. This news article from a South Carolina paper is broadly accurate as the information algins with publicly available information such as Google acquiring companies such as DeepMind and with my own knowledge. However, the article is limited by its simplistic description of the field which is not highly informative. It is definitely useful to the dissertation though as it highlights the high level of investment into AI in 2014, showing that as recently as 2014, a large amount of AI was still being researched as opposed to implemented. It also has use as it highlights the advanced capabilities of NLP, an area of AI that many are currently using to research healthcare bots.

(Bender 2019). This article describes a common problem of AI in healthcare, its lack of transparency (i.e. the fact that doctors are unable to see what it is doing and how it reaches its decision) or "black box" nature. The article features interviews of professionals who sit on both sides of the fence. A computer scientist at the Massachusetts Institute of Technology calls the black box problem a "myth" something which I feel is simply untrue given the sources such as (Faggella 2019) and (World Medical Innovation Forum 2019) which feature healthcare and machine learning leaders who all say that the black box problem is one the largest issues when it comes to implementation. Furthermore, legislation such as the one in the EU (Huss 2018) show just how seriously the problem is viewed. However, the piece goes on to highlight critics who argue that if a doctor cannot trust the result of an AI then neither can a patient. The piece also says that deep learning companies are actively in the processing of developing tools to interpret deep networks although very few tools are currently available. Given the suggestion that there appear to be a trade-off between interpretability and accuracy, one scientist (Goldenberg) concludes that the best approach is to build the best possible system and then develop tools to make it as interpretable as possible, without compromising the accuracy of the network. This article is valid as it appears to be neutral (due to the fact that it features a range of viewpoints from experts) and is extremely useful as it provides insight into one of the biggest problems with AI in healthcare and the contrasting viewpoints of experts on the matter. And ultimately, I agree with the viewpoint of Goldenberg although I do accept the validity of the other viewpoints presented here as well. But to me it shows that the black box issue is a problem that has yet to be fully overcome but could quite possibly be combatted before too much longer.

(Bloomberg Quick Take Originals 2018). This Bloomberg documentary assesses the rise of artificial intelligence with a particular focus on its birthplace of Canada. The purpose of the piece appears to be a mix between to inform and to entertain (as shown with its rather informal and comedic tone). The piece is also likely to be somewhat biased as it features an interview with Justin Trudeau (the current prime minister of Canada) who is talking about Canadian contribution to AI. However, he does raise the importance of ethics in AI, something which is arguably most vital in the medicine industry. Whilst the contents of the source are accurate, they are mostly irrelevant and therefore I have chosen not to use this piece in my dissertation. However, the more general points about AI have been useful in understanding other resources.

(Booth and Barr 2020). This Guardian news article summarises the findings of The Office of National Statistics (a UK government department) that finds that black people are four times more likely to die of COVID-19. It also found that black people are twice as likely to die of COVID-19 than white people when factoring in health, age, and socio-economic factors. This shows that black people are typically worse off when the aforementioned factors are combined. It is still unknown why ethnic minorities die disproportionately more when exposed to the disease but because this gap in death rate is also seen amongst other demographics such as Pakistani, Indian and Chinese households, one can infer that racial bias or inequity may be a large factor in this. These figures are reliable as they are clearly there to inform and performed by a neutral government agency. They show a strong likelihood of unequal health status and / or healthcare in the UK. This once more links back to the idea of AI possibly furthering this gap and also shows the importance of treatment methods that do not enhance the gap in quality of healthcare treatment between those of various races, genders, and sexualities.

(Bossmann 2016). This article details some of the ethical considerations of artificial intelligence, such as the potential of furthering of racial bias, enabling immoral deeds such as use of AI powered military drones and potential to cause high levels of unemployment. Particularly relevant to this dissertation are the points it makes about poor training data reinforcing human bias and the need to establish precedent for the legal responsibilities of an AI system. This piece is however not a serious academic discussion and more of a voicing of fears that may become realised in the future. Whilst the focus is primarily on the future, it does highlight some instances of recorded unethical AI such as when a piece of software determined that a black person was more likely to commit a crime. The piece uses a few of these use cases to back up its argument lending some credibility, but the focus of the piece is mainly on future concerns, which are not highly relevant to my project. The piece's purpose may be to get people to read the article, possibly leaving room for exaggeration, as well as to start a discussion. The piece is not extremely reliable as a lot of the content is opinionated and coming from somebody who is not an AI expert, but the piece was included as the fears voiced are common and consistent with others. Bossmann's arguments are justified with cases and is of some relevance to social drawbacks of AI in healthcare.

(British Heart Foundation 2019). This piece by the British Heart Foundation is designed to inform about the condition of Atrial Fibrillation, one of the most common cardiovascular conditions. The British Heart Foundation describes symptoms of AF, types of AF (such as paroxysmal) as well as treatments. This piece can be trusted as it clearly has a purpose to inform, because the British Heart Foundation have a high degree of knowledge and expertise in cardiovascular diseases and because everything it says about AF can be verified by other reputable health organisations. Therefore, the piece is useful as it provides a detailed explanation of the condition and that it can be treated effectively and that the condition can be intermittently present.

(Brooks 2018). This news article describes the FDA's approval of IDx-DR, an AI system that detects diabetic retinopathy. Arguably even more exciting is the fact that system has been approved to operate without an expert needing to be present or verify the results. The device determines whether a patient is "negative for more than mild diabetic retinopathy; rescreen in 12 months" or has "more than mild diabetic retinopathy detected: refer to an eye care professional". This technology enables a much larger range of diabetics to be scanned for the condition as no professional is required to analyse each scan initially (which of course means that a far larger number of people are able to be screened for the condition). The systems achieved a roughly 90% accuracy rate. The report is accurate as all of its findings can be verified via the FDA, the IDx-DR website and through the study performed to determine the accuracy of the system. As such the source is valid and relevant as it links into this theme of AI enabling a much larger group of people to be assessed for a disease as it speeds up analysis and requires less professional help. Similar to the Apple Watch, this device ultimately refers people for human healthcare if a condition is detected which is perhaps limitation of the software currently.

(Cam, Chui and Hall 2019). This 2019 survey is essentially the same as resource (Chui and Malhorta 2018) it just details the survey performed in a different year. It states that commercial AI usage has risen and that it shows benefits in industries that do use it. However, it also highlights that many have not made much use of

the technology as barriers remain before use can be widespread. The survey is useful as it provides a broad overview of the state of commercial AI but has is not directly mentioned in this dissertation as the focus is on use in the wider business world, not healthcare.

(Cambridge Dictionary). The definition of data analysis is obtained from a highly reputable dictionary and is aligns with my own knowledge and other definitions. Understanding of data analysis is useful when analysing models such as neural networks which are used in healthcare.

(Canalys 2020). This is a detailed analysis of the performance of smart watches such as the Apple Watch in the first quarter of 2020. It is performed by the reputable tech analysis firm Canalys and as such is likely to be well researched as the reputation of the company is dependent on the accuracy of such reports. The piece shows that the Apple Watch is the dominant smart watch brand and its high shipment numbers show the large potential of AF detection software across such a large group of people.

(Cancer Research UK 2019). This is a set of statistics published by the charity Cancer Research UK about the survival rates of breast cancer at each stage of diagnosis (e.g. survivability if it is identified at Stage 1 compared to Stage 3) as well as other survival statistics. The statistics highlight that the early diagnosis of breast cancer leads to much greater survival rates with 97.9% of those who were diagnosed at stage 1 surviving for more than 5 years, compared to 72% and 26.2% for stage 3 and stage 4, respectively. The source comes from one of the largest charities in the UK whose primary goal is research into cancer to improve survival rates. As such, statistics of this sort are highly likely to be accurate as the integrity of such a charity would be diminished if such statistics were false. Of course, one could argue that they may be biased to exaggerate the risk of death from cancer and the need to get checked up regularly, but this is clearly not the case as the data stems from the office of national statistics. What this does show is the potential of AI that speeds up mammography to allow for more frequent scans for breast cancer which would mean that more cases were identified early, leading to a larger number of people surviving breast cancer.

(Capritto 2019). This news article talks about the FDA's approval of a small sensor that is used alongside a phone application to measure heartrate and can be used to detect conditions such as atrial fibrillation. The report can be trusted as the information in it can be verified through other articles, FDA records and Alivecor's statements (the company who created the product). Therefore, the source is valid.

(Carfagno 2019). This news article describes how the use of the first FDA approved AI technology, IDx-DR, used for lesion detection is rapidly growing in its use. The article is verifiably accurate as papers about the accuracy of IDx-DR as well as articles about IDx-DR being an FDA approved healthcare AI are easy to find, showing that the author has done due diligence. Therefore, the accuracy can be trusted, even if the interview with the founder of the software may lead to a slightly optimistic view of its capabilities. However, the article's claim of IDx-DR being the first FDA approved AI system is perhaps slightly misleading as Artery's software appears to qualify as the first approved medicinal AI. However, the article does go on to clarify that IDx-DR is the first autonomous AI approval as it can be used without a qualified professional present (i.e. it is allowed to diagnose as opposed to just advise).

(Castrounis 2020). This in-depth introduction into machine learning (which is the first piece in a wider course) provides a detailed understanding of the processes by which machines learn such as supervised and unsupervised. It is much more in depth than a resource like (Tutorialspoint 2020) and is also very relevant as it highlights potential uses of unsupervised learning methods in medical AI (such as the clustering of data, something which may be useful to categorise groups of patients into certain categories). The content of this article aligns with widely accepted AI knowledge and matches a range of other advanced insights into the topic such as (Jurafsky and Martin 2019). Therefore, the unreliable nature of (Castrounis 2020)'s medium is of little importance, particular as the author is a specialist in data science and machine learning. As a result of the accuracy and balanced nature of the resource, it is clear valid.

(Chandrasekhar 2019). This article reviews Apple's public statements, Apple's revenue documents and various expert analyses to give a rough overview of the total sales of the Apple Watch. The piece uses a range of reputable sources and insights from various experts to roughly track sales and shipments of the watch to successfully show that the Apple Watch has sold many millions of units and continues to perform

well for the company. As a result of its use of reputable sources and direct quotes from the company, the information presented is clearly reliable and hence the source is valid.

(Chen et al 2016). The piece takes multiple approaches to estimating the economic value of artificial intelligence in the next ten years. It cites identifying new drugs as one of its future uses. The piece is written by a team of reputable authors who are qualified in economics and the methods used to estimate the economic value are sound. However, the piece is based on speculation alone and the piece explains that "calculating a single accurate estimate of AI's economic effect is difficult (if not impossible).". Prediction of the future is unreliable but in the context of this dissertation, the estimate conveys the idea that AI is predicted to be worth a large amount in the near future. The piece was released in 2016 and as such is slightly outdated, but the estimate is still valid to reference.

(Chui and Malhorta 2018). This a survey carried out across a range of companies and focuses on industrial artificial intelligence adoption. The 2018 study concludes that AI adoption is increasing rapidly in business but that a large number of companies have little to no AI use. The study highlights that in some areas, AI is already used frequently but that in others, it is deployed in one or fewer aspects of the busines. The survey is reputable as it is published by a global institute that is known for studying specific markets and trends, as such the data is bound to be accurate and obtained from a range of companies. I did not include this source in my dissertation as it focuses more on the wider use of Artificial Intelligence as opposed to strictly in the healthcare sector, however it was utilised as part of my formative reading and helped me to understand the general levels of AI usage.

(Cireşan, Meier and Schmidhuber 2012). This academic piece details the creation of a deep convolutional neural network to attempt to recognise handwritten digits using the MNIST dataset, a set of 70000 handwritten digits. This network achieves an accuracy of 99.77% on the dataset, which is highly impressive, particularly when considering that the MNIST dataset is known to be imperfect (i.e. a very small number of digits can be misidentified by humans as they look very similar to other numbers). I have no doubt that the piece is accurate, as other state of the art networks are known to achieve similar performances. This paper is very thorough and describes both its architecture and training method in a way that gives me no reason to believe that this is anything but true. As such, the source is reliable and is relevant as it shows the potentially of AI to achieve near perfect accuracy in image recognition tasks. This is highly useful in healthcare as many doctors analyse images such as mammograms, X-ray scans or MRI scans to reach a diagnosis.

(Countrymeters 2020a). This is a website dedicated to calculating the world population. It says that as of January 1st, 2020, the world population was estimated to be 7,763,035,303. The site seems to use a range of reliable sources and the estimate is in line with other estimates. Of course, this is only an estimate and the methodology used is not clear and therefore the number is likely to be off. However, given that other estimates are similar and the range of resources it appears to use in its calculation, I conclude that this estimate is a valid one. This also relevant as it can be used to calculate an estimate for the economic impact of AF detection in the Apple Watch.

(Countrymeters 2020b). This resource has the same publisher as (Countrymeters 2020a). This source estimates the population of the USA and appears to be using valid and reliable resources to reach its estimate although the actual method used is unclear. As this estimate aligns with other estimates, I conclude that the estimate is a valid one.

(Dankwa-Mullan et al 2019). This comprehensive review of AI systems that have been researched with the potential of being used to treat diabetes concludes that AI has the potential to revolutionise the field as it offers greater accuracy and efficiency than current protocol. The piece is a thorough assessment of all relevant research into diabetic diagnosing and treating AI, with over 450 studies looked at including the most notable ones being analysed to some depths such as IDx-DR (described in (Abràmoff 2018)). This piece uses a range of reliable and open resources and is a comprehensive and valid analysis of the current state of AI in the field of diabetes and as such is highly valid. The piece shows the wealth of research occurring and the comparatively far fewer number of FDA approved uses as well as the ability of AI to generally outperform human doctors in various fields.

(Dastin 2018). This Reuters news article reports on Amazon's scrapped artificial intelligence system that was used to scan resumes to find the best applicants. The system was trained using Amazon employment data to identify the best candidates. However, Amazon employees are predominantly male which lead the system to conclude that female applicants were inherently far weaker. This piece is published by Reuter, a reputable news organisation, which features interviews from anonymous Amazon employees (who presumably have been verified by the author to actually work for Amazon). Furthermore, Amazon did not deny this to be true but said that the tool "was never used by Amazon recruiters to evaluate candidates.". Therefore, I conclude that this report is accurate. It is also relevant as it shows one of the massive problems with the black box nature of AI, it is good at training a model to effectively categorise data with relationships but that it may sometimes learn the wrong things and fail to generalise. This is an important concept which could have disastrous consequences in healthcare, if for example medical imagine training data contains a disproportionately high number of white individuals, an AI may falsely assume a correlation between colour of skin and a certain disease. This shows the importance of carefully considering training data, developing methods to understand what an AI uses to make its decisions as well as limiting an AI's access to irrelevant information e.g. sexuality.

(DeepMind 2020). This documentary documents the development of an artificial intelligence system named AlphaGo that learned to play the board game Go (a game typically deemed impossible for computers to play well) and beat the world's best Go player. The system used a reinforcement learning algorithm to master the game as well as a Monte Carlo based tree search and a neural network to prune the search tree to play the game Go. What was so impressive about this was that the system was entirely self-taught and learned only through playing games against itself. This versatility and range of machine learning techniques is impressive and suggest that techniques beyond supervised learning can be applied to the field of medicine. The ability of AlphaGo to beat the Go world champion demonstrates the ability of AI to massively outperform humans even in techniques where its brute forcing skills are far less effective. It essentially shows that AI is applicable to a broad range of things that one may never expect an AI to be able to perform well at, including many tasks in medicine.

(DW Documentary 2019). This documentary looks into the ethics surrounding artificial intelligence systems. The piece discusses a wide range of ethical considerations regarding AI use and particularly highlights the lack of legislation regarding ethical AI and the incomplete nature of governmental guidance on ethical AI. It talks about the threat of AI in a range of things. The documentary is published by a German public broadcast service, DW, on their YouTube channel dedicated to documentaries. The piece is therefore likely to be well researched and neutral. A large amount of the documentary is based on interviews with certain experts which could lead to a biased view of the overall ethicality of AI as the people being interviewed are focusing solely on the ethical disadvantages of AI, although these downsides are clearly still valid. The piece is focused on broader AI use as opposed to just medicinal AI which limits the relevance of the source. However, this concept of weak legislation, weak ethical guidance and potential to cause serious harm are somewhat relevant in showing that AI as a whole has many hurdles to overcome, particularly if it is to be implemented in a life-saving industry such as medicine.

(Egede 2006). This analysis of three studies into racial inequality in healthcare concludes that there is a racial disparity in healthcare although the piece goes on to find that more analysis is needed to determine what extent of this can be attributed to discrimination and what extent of this can be attributed to socio-economic factors (as minorities are typically less well off, which some argue is a result of systemic racism). The piece thoroughly analyses these reputable studies and as such, I believe these findings to be valid. The author shows that adjusting for perceived discrimination does not remove racial inequity, which the author suggests shows a combination of discrimination and socio-economic inequality. This is important as poorer healthcare can lead to a deterioration in socio-economic wellbeing which is precisely why racial bias in AI could have an adverse socio-economic impact on minorities if not addressed.

(El-Amrawy and Nounou 2015). This academic paper measures the performance of wearables such as the Apple Watch and compares their accuracy in measuring metrics such as steps and heart rate to professional devices. The study found that the Apple Watch had a 99.9% accuracy in measuring heart rate when

compared to a clinical device which was the highest accuracy of all devices tested and shows that the Watch acts at the same level as advanced pulse measuring equipment. The piece is published by two academic individuals and all the methodology seems to be thorough and fair, leading me to conclude that its findings are valid.

(Faggella 2019). This article is based on and includes a discussion between two machine learning and healthcare experts. The consensus is that AI is likely to become widespread in healthcare in the immediate future but that its current implementation is far more limited. This is due to issues such as the black-box nature of AI but also due to the structure of the healthcare industry. They say that there is a lack of incentive to invest in research in the field because stakeholders have not seen enough to be convinced that the research will return their investment. This speaks to the problem of not enough research being translated into actual implementation yet, creating a repeating loop where there is a lack of proof to show that investment into AI is worthwhile, thus leading to lack of investment into research which leads to a lack of proof that AI is worthwhile. However, I disagree with the experts slightly here as I have seen a wide range of research into AI that shows extremely successful software. But I do generally agree and accept their point as they work in the industry although I feel that it is not a lack of research that is the problem but more lack the lack of research being implemented. What they point out, which is invaluable, is that because it is such an emerging market, many investors are hesitant to invest in the field which leads to slow growth. However, this is an important point as it links to an underlying theme of the dissertation (that research does present socio-economic value as it leads to more investment from stakeholders and thus adoption of AI in healthcare). All in all, this resource is highly reliable as it is written by an expert who has interviewed the people who are most likely to understand in detail the current state of AI in healthcare.

(FDA 2019). This is a draft of potential FDA guidance regarding the use of software in a clinical environment that shows a willingness for approval of software in “non-serious” situations although it shows an openness and uncertainty about software in more critical situations. It is important to note that this is a draft and not actual guidance and therefore can only be viewed as the general thought process of the FDA. The draft is current as it was released in September of 2019 which suggests that the FDA’s current stance is similar and as such is a relevant document as the socio-economic impact of research into AI is directly linked to the ability of these research projects to be implemented by healthcare providers (which would require FDA approval in the USA). And of course, this document is bound to be valid as it is written by the FDA.

(Fox 2018). This NBC news article details the unveiling of a new Apple Watch in 2018 which has the ability to detect AF. The piece goes on to say that the FDA has approved use of this technology in the watch. This article is published by reputable news organisation NBC and can be varied by other sources such as [Figure 2], [Figure 3] and the video recording taken from the conference in which the watch was unveiled. As such, the piece is clearly accurate.

(Freethink 2018). This YouTube video features members of the Montefiore Medical Center of the Albert Einstein College of Medicine discussing their use of AI in their practice. They highlight the extremely large amount of data they have to deal with which they say is advantageous as it allows them to train highly effective AI models. The resource is flawed as the video was produced in partnership with Intel, a computer company, whose healthcare team is working with the hospital members to develop the systems. As such, this video will almost certainly paint their systems in an overly positive light detracting massively from the validity of the source. There is still some validity as these professionals clearly are benefiting from AI in the field and do know what they are talking about. This idea of larger data sets leading to more accurate models is important in the context of medicine as hospitals typically store large amounts of data on the medical history of their patients which would facilitate more effective models.

(Frick 2007). Frick et al. describe the large economic impact of blindness in the USA each year, with an average impact of $5.5 billion spent on medical care and 209000 quality-adjusted life years. A comprehensive survey was performed to obtain data used in this peer-reviewed piece and as such, I have a high level of confidence in the findings of this journal entry. Through effective screening of diabetic retinopathy, the number of cases of blindness could be significantly reduced which would result in large

economic benefits (through reduced healthcare expenditure and ability to work effectively) as well as social benefits through less loss in quality-adjusted life years.

(Gartner 2020). The number of sales of smartphones in the last quarter of 2019 along with the overall sales in that year are analysed in this piece. Produced by Gartner, a reputable technology research organisation, this information is likely to be accurate as the purpose of the company is to publish accurate and reliable research (along with the fact that much of the data presented here can be verified through earning reports of each company). This piece shows the vast number of mobile phones sold each year, with around 1.5 billion sold in 2019. This is relevant as it shows that screening for conditions such as AF is available to a large demographic of people by making use of software such as to one mentioned in (Loon 2018). This is important as it enables doctors to screen a much larger pool of people for AF without having to distribute limited resources.

(Gillham et al 2018). This report by PricewaterhouseCoopers is written by a team of highly qualified economists and is a comprehensive piece that models the impact of AI to estimate its value in the future. The impact is assessed thoroughly analysing a wealth of data and creating a strong model. As such, this is perhaps the most accurate model one can find that assesses future worth. However, it is inherently limited by the fact that it is trying to predict the future and as such will probably be proven incorrect given time as predictions are very rarely precisely correct. However, I have utilised the source as I have clearly stated that it is an estimate of the future and as an estimate, this piece is perhaps the most thorough (and thus probably best) estimate one can obtain.

(Glocker 2017). This talk by Ben Glocker details the use of deep learning techniques in healthcare and particularly focuses on neural networks using both supervised and unsupervised learning techniques. The piece shows just how effective AI are at complex image analysis, something which Glocker demonstrates can and is being used in medical imaging analysis. Glocker is a highly qualified professional, giving lectures about medical image computing at Imperial College London and is a senior member in a research group that focuses on applying machine learning techniques to biomedical image computing and medical computer vision. Given his high level of expertise and given that many of the cases he speaks of can be verified, it is clear that this source is highly valid, particularly showing the potential for AI in medical image analysis.

(Google 2019). This piece by Google discusses the importance of data sets when training a machine learning model, highlighting that a data sets of high quantity, high accuracy, and minimal skew (i.e. representative data) are traits that are needed to produce the most accurate models. Google implies that more complex systems are only feasible with relatively large data sets. The piece is clearly intended at developers as it is part of a machine learning course produced by Google, meaning that the information presented is accurate and reliable. As it aligns with my own knowledge and other resources, I conclude that the information presented here is valid. This idea of the need for large data links back to a recurring theme discussed in (Freethink 2018) and (World Medical Innovation Forum 2019) and the concept of a “skew” in training data being bad links to theme of potential bias (such as racial bias) in AI systems as discussed in (Dastin 2018).

(Google Developers 2018). This keynote session talks about how companies such as Google are attempting to utilise machine learning advances in the field of healthcare. The talk uses a range of medical examples to show the promise of using AI in healthcare, with the theme of artificial intelligence being competent at image recognition running throughout the talk. The talk may be slightly biased as the speakers are associated with Google and their parent company and as such may wish to highlight Google’s machine learning library: TensorFlow. However, this is a negligible concern as the two are qualified professionals who use a range of valid examples to make their points, making the source valid. As the talk focuses so much on possible future application, it is slightly irrelevant. Much more relevant is the ability of AI to perform so well at image recognition, a core theme of the dissertation, and the fact that these industry leaders are confident that AI can, as it is at the moment, be successfully applied to medical problems and perform well.

(Gottlieb 2019)/ This is a statement published by the FDA announcing their intentions to work with the community to produce a set of guidelines to ensure ethical and good practices are maintained when producing AI in healthcare. The statement also underlines the FDA’s willingness to embrace the technology

as they feel it has tremendous potential benefits. This statement is of great relevance as it shows that there is a lack of clear guidance available about medical AI, which will of course lead to far fewer implementations of AI, that ethical AI is of great importance (and that there is a need for guidelines to overcome some of the hurdles medical AI presents), and that the FDA is willing to accept and work with companies to implement AI in the field. Therefore, the source is of great relevance.

(Guttmann 2018). This chart from Statista shows that almost 50% of AI in marketing is used for data analysis. This resource was included because the focus of the project was originally going to be on healthcare and data analysis, however I concluded that focusing on solely healthcare was more appropriate. Statista is a somewhat reputable website for statistics; it is a far less reliable source for non-paying members (such as myself) as it limits the access to the number of articles one may view and does not show which sources were used unless one pays for the premium membership option. That being said, I know that a large amount of AI in marketing is data analysis and as such this source is probably reliable, but it is difficult to verify this as I am unable to see the sources this chart uses. Therefore, I conclude that the information is probably reliable and is definitely correct in terms of AI in marketing involving data analysis, but that it is too unreliable to use. Furthermore, the information is largely irrelevant to my dissertation although the inference that AI is good at analysing large amounts of data (particularly about customers) is applicable to healthcare, particularly as other resources ((Freethink 2018) and (World Medical Innovation Forum 2019)) say that AI is used to analyse the data of patients and that hospitals collect enormous amounts of data on patients.

(Hallström 2016). Hallström details how a feedforward neural network functions, explaining its architecture and the concept of weights and biases. This resource has been very useful in terms of gaining a deeper understanding of how machines learn and thus their limitations and accuracy which has helped me in identifying weaknesses of AI in healthcare. The piece also goes into detail about the gradient descent algorithm, an optimisation technique for neural networks. This piece is consistent with general understanding of the topic and my own knowledge. The article is published on medium, a website that is a reputable resource for machine learning and data science articles.

(Hannon et al 2019). This paper analyses the proportion of strokes occurring in North Dublin that are related to AF. The piece concludes that 31.2% of strokes were AF related and that a prior stroke was twice as likely in AF suffers than non-AF suffers. The piece is comprehensive and has a fairly large sample size although the potential for selection bias is there (although steps were taken to minimise this risk). The study does appear to be reliable as it is written by a group of academics and because both the methodology and data seem to be proper. However, there is the potential that the true figure is not 31.2% as this number is based on 568 stroke incidents. Despite this, the estimate is still reliable and demonstrates the fact that AF drastically increases likelihood of stroke (and strokes have socio-economic ramifications as they can lead to disability and death).

(Harris 2018). This news article talks about the levels of funding that healthcare AI start-ups were receiving, with the headline being that over half a billion dollars was invested in the first half of 2018 alone, although there does appear to be less interest than in 2016. However, this level of funding is important is at it may negate one of the key criticisms of the healthcare AI mentioned in (Siegersma et al 2019) and (Faggella 2019) about the lack of funding into research discouraging stakeholders from adopting the technology. The research this report is based on (which is performed by the same company as the one writing the article) is thorough and verifiable in regards such as its reference to founded companies and through public records of funding. As such, I conclude that the report is useful from the perspective of showing that there is a large level of investment into AI in healthcare right now and as it is published by a company who focus on giving insight into technology usage in healthcare.

(Hart, Pearce and Aguilar 2007). This article provides an analysis of 13 randomised trials on the use of certain drugs to reduce the risk of strokes amongst AF patients and concludes that use of Warfarin can reduce stroke risk by 60% for AF sufferers. This shows an enormous economic benefit in improved diagnosis and screening for AF as proper treatment can clearly reduce stroke risk and hence increase both quality and length of life of sufferers of the condition. This piece was written by a member of the University of Texas'

medical department and has a sound methodology that leads to a high level of confidence in its findings. Thus, I deem the source to be both valid and relevant.

(Harvard Medical School 2018). This live streamed Harvard Medical School lecture discusses the future of AI in medicine by looking at current research and use as well as issues to widespread implementation. The piece states that models are" as good as the training data" and highlights the need to address biases in data to ensure truly intelligent models. These are recurring themes which are discussed in a number of resources such as (Google 2019) and (Dastin 2018) and are therefore clearly valid issues that are prevalent with medicinal AI. The purpose is clearly to inform and as the lecture is being carried out in one of the most prestigious academic institutions in the world, the contents are reliable. Therefore, I feel the source is of high validity.

(Harvard Medical School 2019). This Harvard Medical School Seminar discusses AI in healthcare. The focus is on AI systems that are being (or have been) used in healthcare or are being researched. In short, it analyses functioning healthcare AI. Whilst (Harvard Medical School 2018) is much more focused on looking at a general overview of the future of medicinal AI, (Harvard Medical School 2019) is a compilation of isolated instances of healthcare AI. The piece highlights the ability of AI to perform at similar and better levels than humans, which is a recurring theme of research and implementation of AI. One talks about pattern recognition and another looks at an AI that analysed blood types to determine appropriate treatments. The speakers and the academic institution hosting the speakers are reputable and their anecdotes are verifiable lending reliability to the source. I have not used this piece in my dissertation as the focus is on individual and often non-FDA approved systems which are hard to assess when attempting to a look at an overall impact of AI (anecdotes are not as strong as data). Many of these AI systems are also atypical and as such are not broadly representative of most systems in the field. Therefore, the source is valid but has not been directly used.

(Hicken, Bowen and Woods 2020). This podcast on AI in healthcare interviews Microsoft Australia's Chief Medical Officer (Doctor Nic Woods) who discusses the general state of AI in healthcare. Doctor Woods talks in detail about how much of the research into medicinal AI is centred around the analysis of medical scans to form a diagnosis. Given the qualification of Doctor Woods and the educational focus of the podcast, I would conclude that this resource is valid even if it may be limited by the fact that it is coming from the perspective of a Microsoft employee who may give a more positive view of the state of AI in healthcare when compared to a radiologist currently working in a hospital, for example.

(Huss 2018). Huss' blog post about the potential hurdles of implementation of AI in healthcare is a well thought out piece that points out a number of important flaws such as the greater need for transparency (something which is legally required of for AI healthcare devices in the EU). He also highlights the problem of doctors being unable to trust AI and its black box nature (which is a recurring theme across multiple resources). Despite the general content and critiques of AI being fair, the piece does not back many of its arguments up (although it does correctly highlight relevant legislation) and is somewhat opinionated. Despite the lack of formality that comes with a blog post though, the flaws of AI are agreed upon by other resources and experts such as (Faggella 2019) and (World Medical Innovation Forum 2019)). Furthermore, the blog has the potential to be biased as the platform is developing a platform that addresses one of the issues described in the blog, giving them incentive to exaggerate the downsides of AI and particularly of the downside of "engineering debt", the issue the platform claims to combat. However, I have included the sources as the general critiques are valid and shared by other experts even though there is a conflict of interest.

(Husten 2019). Husten summarises concerns over the "hype" surrounding the atrial fibrillation detection technology in the Apple Watch. The piece lacks neutrality and is largely biased and opinionated with Husten arguing that the Apple Heart Study will lead to lots of anecdotes but little useful data. He argues that the fact that the trial was not a randomized controlled trial is a limitation of the study, which is certainly a valid critique and one of the largest flaws with the trial. However, I feel that Husten's views are not entirely fair as the large sample size allows for a relatively high degree of confidence in the performance of the Watch. Furthermore, the view that the study led mostly to anecdotes is unfair, in my view, as a large amount of

useful data was obtained such as its specificity and sensitivity as well as the percent of cases it identified compared to the number of cases one may have expected it to identify. As a result of this, I feel that most of the critiques are invalid or unfairly negative, but I also feel that some of these viewpoints are valid. The trial was not perfect as it was not a randomised control trial, because it relied on self-reporting, because it relied on online self-enrolment (potentially leading to a more technologically competent and hence probably younger sample) and because the study failed to meet its target number of participants older than 65 (something which is important as AF is far more prevalent in those who are older). From this source, I took away that there were flaws with the design of the Apple Heart Study, even if I perhaps reached a different decision to Husten as I believe that the large sample size of the trail has led to results in which one can be rather confident in. The FDA's approval of the system strengthens my confidence in the findings of the trial.

(Jiang et al 2017). This paper by Jiang et al. was a highly useful source in understanding the current state of AI in medicine. The piece details current use cases and research into AI in healthcare. The piece is extremely thorough, with 69 citations and the pieces' explanation of techniques such as suppport vector machines, neural networks and deep learning align with other sources and general knowledge. It is published in one the most reputable journals, The British Medical Journal, and is peer reviewed which means that a high degree of trust can be placed in both the accuracy and reliability of this resource. Perhaps the only limitation is that the source was published in 2017, as AI in healthcare is rapidly evolving. However, 2017 is still relatively recent and the content broadly aligns with my impression of AI in healthcare today. This idea of prevalence of AI in both implementation and research for the healthcare industry links to the socio-economic impact of AI as the advancement and relative amount of research and implemented systems in the industry is linked to its overall impact.

(Jurafsky and Martin 2019) describe, in detail, the structure of a neural network and the use of an optimisation technique known as gradient descent to ensure that the network outputs near optimal values. They then go on to describe how this can be used to in language models that predict which word to write next given some number of previous words. This paper is a detailed academic piece published by Stanford University. The piece is extremely well sourced and everything it says is consistent with my own knowledge (which I partially acquired from programming my own neural network to develop the tool for [Figure 4]) as well as a wide range of other resources. The purpose of this piece is clearly to inform and teach, and links in with widely known knowledge of the field of machine learning. It demonstrates one use of AI in natural language processing. This source is, in short, very reliable.

(Kanber et al 2019) This paper describes the use of a high dimensional neural network in treating multiple sclerosis which outperforms models of lower dimensionality. Once more this piece is published in a reputable journal by qualified authors and has been peer-reviewed which gives me a high level of confidence in the validity of this source. This idea of greater dimensionality (i.e. more complex structure) being effective indicates that neural networks can be highly effective at performing tasks the human brain does, given enough scope to carry out these tasks, showing the potential of systems in a wide range of advanced, yet limited in scope, tasks. This recurring use of AI in medical imaging shows potential social benefits as, for example, a general X-ray scan could theoretically be scanned by multiple AI systems in a matter of milliseconds in order to screen for a whole range of conditions that may have never been detected otherwise.

(Liu et al 2019). This is one of the most substantial pieces of literature on research into machine learning in healthcare. This piece provides a comprehensive analysis of a range of 69 studies about AI systems in healthcare and concluded that the algorithms operated at a level similar to healthcare professionals. This lends massive strength to the underlying idea of this essay: that the ability of researched AI to outperform or perform comparably to doctors is typical for such projects. As this study analyses a range of other papers (all of which it links to), the authors have clearly performed the analysis they claim to have and therefore this is source is both valid and highly relevant to the essay.

(Loon 2018). This piece on Fibricheck's website details the fact that the FDA has approved their atrial fibrillation detection software that makes use of a smart phone's built-in camera. This information is likely to be accurate as it is published as it is published on Fibricheck's website, a medical organisation who would be

penalised for spreading misinformation about their products, although it could also lead to bias and a view of the product that is overly positive. However, the broad content of the article can be confirmed as the product is available and as its approval is logged by the FDA. This software has the potential to save many lives as it makes use of a smartphone which has an audience of many billions (a much larger size than even the Apple Watch). Although it does come with the downside that constant monitoring of pulse is not possible. It does link to the wider theme of AI making healthcare more accessible and available to a wider sample of people.

(Lungren 2018). This talk by Doctor Matthew Lungren talks about AI use in radiology as a whole and discusses both advantages and disadvantages of the field as well as the fear of some that radiologists will become obsolete in the next few decades. Lungren talks about the fact that AI is able to greatly speed up time for scans to be analysed as it is far faster than it is possible for a human to be. The piece also explains what a saliency map does, a concept also discussed in (World Medical Innovation Forum 2019), and how it can reduce the issue of the black-box nature of AI. The talk is given by an expert at Stanford, the content of the talk is clearly accurate, and his purpose is to be informative. Therefore, the source is valid, particularly as it is so relevant to the breast cancer AI system that this dissertation evaluates in some depth.

(Machado 2016). Machado describes the use of supervised, unsupervised and reinforcement learning techniques in machine learning. The piece is not highly detailed but mentions the broad idea of each one and does so accurately as his supervised section matches sources such as (Sanderson 2017). From other research and my own knowledge, the existence of unsupervised and reinforcement methods is well documented with algorithms such as k-means clustering and reinforcement learning and their use cases such as chess algorithms being well documented. As this piece is only used to show that other machine learning techniques exist, its inclusion is appropriate. However, unsupervised learning techniques are not common in medicine although still used as they are good at grouping similar data points for example and reinforcement techniques are practically non-existent in medicine.

(Makary and Daniel 2016). This piece is published in The British Medical Journal, a peer reviewed and highly respected medical journal, which concludes that medical error was the third leading cause of death in the USA in 2016. As a result of the reputation of both the journal and its academic rigour as well as thorough ness of the paper itself, I conclude that the source is valid and its conclusion reasonable. This piece is of course relevant to AI as AI systems that outperform doctors could arguably reduce medical error if programmed well or increase it through poor design decisions such as the mentioned lack of diversity in training data in (Siegersma et al 2019).

(Mannini et al 2016). This journal piece describes the use of support vector machines (an AI technique) to categorise pathological gaits, particularly amongst stroke sufferers. The system achieved a 90.5% accuracy, showing promise for future advancements in the field. This study is performed using a rigorous and scientifically sound method that has a high accuracy level. It is also published in a reputable, peer-reviewed journal meaning that the information will have been checked by other experts which I concluded enables me to have a high degree of confidence in the results of this piece. The purpose is to objectively present their research although there is always a small chance that it may be cherry-picked to suit their narrative (although unlikely as this piece appears to be exclusively academic). However, I have used the article as it is valid in the context of an AI system that accurately detects gait class.

(Marr 2017a). This news articles published in Forbes details the first FDA approved machine learning software for use in medicine, an artificial feedforward neural network produced by Arterys's to analyse medical scans of the heart. The piece interviews the founder of the platform. All in all, the piece is highly relevant as it describes the first FDA approval which provides context as to just how recent implementation of AI in healthcare system. The article may well exaggerate its capabilities as the focus is on interviewing the founder, somebody who is unlikely to be completely neutral in the matter, even if his arguments are primarily backed up by facts. The article importantly highlights that in order to gain FDA approval, it had to pass a range of rigorous tests to prove that it functioned just as effectively as humans, which shows how difficult it is to gain approval. This knowledge is highly useful as it links into the socio-economic impact of research as if an AI system is able to perform at a similar level to a human, it is theoretically able to be

integrated into the healthcare system subject to further research, but it at least shows that implementation is feasible for such algorithms. I used the article as it is reliable in the sense that it accurately shows the date of the first approval of a machine learning algorithm by the FDA and as it demonstrates the standard required for such a system to be approved.

(Marr 2017b). This news article by Marr details the training of a deep learning algorithm by Google that uses of 10 million unlabelled images to successfully identify cats. This shows the potential of AI to meaningfully analyse large amounts of data, something which is invaluable to the medical industry where many healthcare providers complain of an excess of data. The article is written by Marr, somebody who frequently writes about AI and is published in Forbes, a well-known news site which enforces journalistic due diligence. The article can be externally verified as Google have published a paper on this AI and one can also verify the article's claims about Google's current other uses of AI such as self-driving cars. Initially, my dissertation was going to have a focus on data analysis and healthcare, but I decided that the analysis would be of greater quality if I focused on healthcare. As such this article was not included as it lacked relevance as it does not talk much healthcare (although it does mention that DeepMind (a Google company) is working to develop imaging AI).

(McCauley 2016). The piece discusses the current state of artificial intelligence in various sectors such as healthcare and goes on to analyse possible future scenarios involving AI. In a survey conducted amongst business leaders, the report found that AI was most advanced in use in the healthcare sector (although it was not significantly more advanced than other industries), although they still concluded that AI was still far from being widely used in the industry and that its use was exploratory. The survey is trustworthy as it spans 203 executives and thus will help paint a decently accurate picture of current AI adoption levels. However, the small sample size means that this view of the healthcare sector is a rough one. As the survey does not focus particularly on healthcare, the picture may be slightly off, but it serves as an apt comparison between AI adoption in medicine and other industries. The paper comes from The Economist, a highly reputable economics source and thus the purpose appears to be merely to analyse AI adoption levels, making it a reliable resource.

(McKinney et al 2020). This paper in the Nature journal talks about the development of an AI system that analyses mammograms in order to determine whether a patient has breast cancer. The system performed highly impressively, reducing false positives by 5.7% and reducing false negatives by 9.4% in the USA. The system also performed favourably when compared to experts in the UK. This piece was published in one of the most respected journals (Nature) which publishes peer-reviewed work. This means that the claims made in this article can be trusted and are accurate. This case is highly relevant to the dissertation as it shows that AI can outperform human doctors as well as taking milliseconds to analyse a scan. Research such as this does have socio-economic implications as it demonstrates the fact that AI can free up doctors to perform other tasks where they are needed as well as reduce the overall cost of healthcare as once such a system is completed, maintenance costs are negligible when compared to the cost of a radiologist. Research of this nature should also help to address the hesitancy medicinal stakeholders feel in investing in the technology as they feel that it is unproven (as shown by (Faggella 2019)). This article was published in 2020 showing just how recent this breakthrough is, helping to understand why there is such limited current use of AI in the field. This research case is used as the typical example of the impact of AI research and therefore is a valuable resource to the overall dissertation.

(NHS 2018). This piece by the National Health Service describes the standard protocol of breast cancer screenings in the UK, such as that women are typically screened once every three years and that one can wait up to (but typically no more than) two weeks to receive the results. As the piece is published by the NHS and aimed at patients, its purpose is clearly informative as it wishes to provide patients with accurate information which makes the source of high validity. It is also relevant as an AI that speeds up mammogram analysis would allow for a shorter wait time for results but also the possibility of screening more frequently than once every three years which also makes this source relevant.

(NINDS 2019). (NINDS 2019) describes information about atrial fibrillation and its stroke risk and states that through treatment, AF sufferers can reduce their stroke risk "by approximately one-half to two- thirds".

(NINDS 2019) is authored by The National Institute of Neurological Disorders and Stroke, a US government agency designed to direct and fund research in the field. Therefore, the purpose of this piece is clearly to inform and present facts regarding the issue, lending validity to the resource. This piece is highly relevant as such a significant reduction in stroke risk through treatment naturally means many lives could be saved and improved through more effective diagnosis of atrial fibrillation.

(Operational Information for Commissioning 2016). This document release by the English National Health Service publishes a years' worth of scanning data from 2015-2016 and analyses a number of things such as time between a scan being performed and receiving a diagnosis, time between booking and receiving a scan and number of scans performed. This is a detailed official document and as such can be trusted to be reliable as the purpose of the document is to be accurate. If it were found that the document was altered deliberately, there would be a large governmental scandal and many people would lose their jobs. Simply put, the authors have no reason to lie and a very strong incentive (not to mention safeguards) to ensure that the piece is true. There is no doubt in my mind that this document is of the strongest validity and is highly useful as it, for example, highlights that some patients can wait up to twenty-one days to receive the results of an MRI scan. This is something that AI could help to drastically speed up.

(Oxford English Dictionary). This online dictionary defines medicine as "The science or practice of the diagnosis, treatment, and prevention of disease" which is clearly an accurate definition. The dictionary makes use of the Oxford dictionary, one of the most trusted dictionaries, making this source reliable and useful to my dissertation.

(Oxford Learner's Dictionary). The definition of artificial intelligence is obtained from a highly reputable dictionary and is aligns with my own knowledge and other definitions.

(O'Dea 2020). This Statista chart shows the number of smartphones users per year. Statista is a typically trusted website used for its quality statistics (although it is less trustworthy for non-paying members). This estimate of the number of smartphone users aligns with a great deal of other estimates and can be somewhat fact checked through the data published by large mobile phone companies. As Statista only publishes research conducted by its team, whose goal is to give accurate data, the piece is likely to be valid. However, I cannot view any of the sources used without purchasing a premium membership which does detract from the reliability of the source. Despite this, I feel the estimate is valid due to the reliability of the author and the fact that other estimates are similar.

(Panch, Mattie and Celi 2019). This peer-reviewed nature journal entry talks about many of the challenges that need to be overcome for widespread AI implementation in healthcare to become a reality. This piece particularly focuses on issues of data ownership and lack of investment in the digital architecture needed to create such an environment. The piece stems from a respected journal and uses many reliable resources to make its points. Furthermore, the conclusion it draws is a valid one and it fairly demonstrates that large steps are needed before AI implementation is a universal healthcare reality. This current limit in infrastructure is important as it shows the limited effectiveness of research as it is harder for these AI systems to transition to implementation and also that research is less cost-effective due to lack of data collection protocol.

(Perez 2019). This article describes how, following a clinical trial, Alexa has allowed certain developers to create medical skills for the Alexa app as long as the comply with relevant medical standards. Similar to (Stewart 2019), this shows the ability for NLP software to make a difference both in the fields of medicine and care. The contents of this article have been confirmed by Amazon, lending the source validity.

(Picasso 2020). This piece describes the three most common types of training categories for machine learning systems: supervised (use of pre-labelled data), unsupervised (data that has no labels) and reinforcement (navigating a model such as a game board and determining whether the actions it took led to a good result). These principles are common knowledge and can be verified by a great deal of machine learning resources. This is relevant as it shows that AI systems in healthcare can be trained in many different ways, allowing for diverse systems that can do many things and does not just restrict AI systems to use of labelled data sets.

(Population Pyramid). This resource shows the population of the USA in 2009. The purpose of the website is to display accurate statistics regarding population and the figures are what one would expect given census data. This piece is important as it helps highlight the prevalence of undiagnosed AF in the USA by using this number alongside the information presented in (Turakhia 2018).

(Rosenbaum & Associates 2020). This piece is a collection of reliable resources that give an insight into the number of medical malpractice claims per year. All the sources it uses are reliable and show a very large number of annual cases although the source has a valid reason to show bias as it is published by a law firm that claim to "HOLD DOCTORS AND HOSPITALS ACCOUNTABLE" which would certainly give it a reason to be biased. However, the data it presents is verifiably accurate such as the fact that John Hopkin's University estimates that around 250,000 cases of medical malpractice occur annually. Therefore, I have included the source as these statistics give a reasonable image of the volume of malpractice claims.

(Sanderson 2017). This YouTube video series describes the basic details of artificial neural networks and does so well, explaining the mathematics that underly the process of some machine learning models that make use of a neural network. Sanderson is an undergraduate in mathematics from Stanford University and is known to produce a wide range of reliable videos on computer science and mathematics. Everything appears to be well researched including an interview with a doctor whose PhD is in deep learning. Once more, the piece is consistent with widely accepted knowledge in the field and also aligns with everything (Jurafsky and Martin 2019) say. The purpose is clearly educational and as such is a reliable source.

(Sanofi 2019). The ethics of AI and potentially social concerns regarding use of Ai in healthcare are discussed. For example, it highlights the potential for unrepresentative data to limit the effectiveness of AI. Facial recognition software that performs far worse on people of colour is one of the examples it uses to demonstrate that this is a flaw with AI that is being seen. This can be overcome with a greater data pool, but there are fears that this issue may never be fully combatted effectively. It also details the worry of the black box nature of an AI, something which other resources on the subject also highlight including (Faggella 2019). The piece summarises the European Union's guidance on ethical AI. Whilst the piece is reliable and accurate so far as justifying all of its points well and as these points are generally agreed on, the piece does have limitations. This is because Sanofi are creating their own ethics code on AI in healthcare which of course would place them in a good position to understand the implications of the technology, but it also gives them a reason to be unfairly negative about the ethics of AI and the EU's guidelines in order to demonstrate the need for a better set. Therefore, I have not directly used the piece as I feel that this is a serious bias. However, I do feel that the source is valid as the ethical concerns it mentions are shared by other experts such as (Faggella 2019), I just feel that the resource might have an incentive to not be neutral. I have used it as formative reading and have considered the ethical drawbacks it cites, all of which are also mentioned by other sources.

(Seto, Leonard and Cafazzo 2012). This piece discusses the creation of a rule-based healthcare system that encodes knowledge of various heart doctors to produce clinical decisions based on factors such as blood pressure. The report concluded that the system led to improved quality of life. The piece shows the potential for rule-based AI systems to be effective. The piece is published by reputable authors and the methodology is sound lending validity to its findings. This piece also highlights how dependent such AI systems are on human knowledge and as such typically only have potential in the automation of simple tasks. Whilst the piece is valid, I did not directly use this source. I used it to enhance my background knowledge, but the source was ultimately not included due to the fact that most rule-based systems are very limited in their ability as they depend on human knowledge. This one was more limited as the rules were not widely accepted rules but merely ones drawn up by a small set of doctors, making it a poor case to use to assess the socio-economic impact of such AI systems.

(Shiffman 2016). This YouTube video series discusses what genetic algorithms are and talks about both the theoretical aspect of such algorithms as well as examples of their implementation with accompanying code. Genetic algorithms can cover a wide range of things and are designed to broadly represent evolutionary mechanisms by prioritising agents that perform best by using their genetic code to create new and (hopefully) better agents. This can be a form of unsupervised learning often used alongside a neural network

and these algorithms have proved effective in mastering videogames such as “Flappy Bird”. This piece is published by a renowned computer scientist who has written a book discussing the topic and the information is accurate as it aligns with other resources and because the implementation of his algorithms function as expected. This source is relevant as it shows the fact that there are a variety of training mechanisms for artificial intelligence systems, many of which do not involve supervised learning (which is useful given that the medical industry has such a large amount of data that is not conveniently labelled for a computer).

(Siegersma et al 2019). This paper reviews a range of state-of-the-art cardiovascular imaging AI which have superhuman or near human performance. This paper concludes that AI holds incredible potential to advance the field but that its implementation has been limited due to a number of reasons such as approval being slow and a lack of research that shows the cost effectiveness of AI in medicine. The contents of this paper are very reliable as it summarises a range of reliable sources expertly and as it is published in a respected journal. The paper is also current as it was published in 2019, meaning that the viewpoint of imaging AI will be broadly accurate right now.

(Silver et al 2018). This paper by Silver et al describes the development of a general reinforcement algorithm that masters a range of board games such as Chess, Go and Shogi. The ability to apply a general algorithm to such a diverse range of complex games shows the promise of such techniques particularly as it massively outperformed the best chess player (including human and non-human players) with only a few hours of training. Through clever search techniques such as Monte Carlo search, it was able to beat Stockfish (the best chess bot) by analysing only 60,000 board states compared to Stockfish’s 60 million per turn. Although reinforcement techniques have yet to be applied to the field of medicine, the promise of such algorithms is clear given their ability to perform so well in games that were previously believed to be impossible for computers to play to such a standard.

(Singh 2018a). This blog by Singh summarises the results of paper (Tison et al 2018) and provides some additional detail and context about the paper. In essence, it summarises (Tison et al 2018) and makes the papers contents easier to divulge. Having read (Tison et al 2018), the contents of this article are clearly accurate and a reflection of (Tison et al 2018), making it valid.

(Singh 2018b). Singh’s article describes AI’s capabilities in image recognition including products such as Google Vision and describes how they are capable of facial recognition, detecting objects, detecting text and landmark detection. Singh backs these examples up with various AI systems that can perform such tasks and when this is considered alongside other prominent AI systems, the contents of this article are accurate and valid. AI’s competence at image recognition is important as much of medicine uses imaging technology such as MRI scans to detect various conditions, which is an image recognition task. This shows the massive potential of AI in healthcare, something which is reflected in the fact that roughly half of FDA approved AI are imaging AI [Figure 3].

(Stanford University 2019). This article published by the medicine department of Stanford University summarises the results of the Apple Heart Study, showing a 71 percent positive predictive value (although this number is believed to be higher in reality as paroxysmal AF may go undetected over the seven-day period in watch patients were monitored using clinical equipment for signs of AF). Stanford is a reputable University whose research is academically rigorous and reliable and thus likely to be accurate. Once more, this piece is extremely relevant as it analyses the real-world performance of the Apple Watch and enables one to estimate the economic and social impact of such AI technology.

(Stewart 2019). This news article describes an agreement between Amazon and the NHS which will see its voice assistant device (known as “Alexa”) relay health advice from the NHS website should a user request such information. This shows AI’s push into care and the ability of natural language processing AI to make a real difference particularly to those who lack digital literacy. However, devices such as “Alexa” fall somewhat outside of the scope of the essay as they do not meet the definition of medicine although they do help to illustrate the use of AI and NLP in areas such as care. The article is accurate as the information has been publicly confirmed by all parties involved.

(Stroke Association 2017). Guidance by Stroke.org talks about what AF is as well as its prevalence and treatment. It points out that AF sufferers are at a five times greater risking of having a stroke (something which can be reduced through treatment) and that an estimated 1.2 million British people suffer from AF. The piece is reliable as it is published by a charity who aim to raise awareness, reduce the number of strokes, and improve the quality of treatment for stroke victims. The purpose of the piece is also very clearly to inform which leads me to see the source as reliable. This piece is important as it shows the need for AF sufferers to seek treatment to reduce their stroke risk which makes the diagnosis of AF patients a very important matter.

(Stroke Belt 2019). This Stroke Belt article details the survival rate of stroke sufferers. Notably, the mortality rate within 28 days of a stroke was 28%, a number which increased to 41% after a year. This highlights both how deadly a stroke can be as well as the long term, irreparable consequences that a stroke can cause. The article is summarising the results of a reputable and well cited article produced by researchers at King's College London and as such, the contents of (Stroke Belt 2019) are both accurate and reliable. Given that (NINDS 2019) highlights the significant reduction in stroke risk amongst AF sufferers who receive treatment, (Stroke Belt 2019) shows that through diagnosis of AF, many lives could be saved. This shows the usefulness of a wearable such as the Apple Watch which allows effective screening of a large population size.

(The Economist 2019). This economist video assesses the potential future of AI in healthcare and features an interview with a pioneer in the field. Given the reputation of the economist, the qualification of Dr Eric Topol (who published [Figure 2] and [Figure 3]) and the fact that the information presented aligns with other resources, I conclude that this source is accurate and valid. This piece crucially highlights a key advantage of AI: it does not get tired and always preforms consistently. It is able to perform analysis tasks in milliseconds which might have taken a human 15 minutes, which is important in things such as imaging as faster analysis enables more scans to be performed. For something like breast cancer, this would allow a greater range of people to be scanned more frequently, something which would save lives.

(Thompson 2019). This book by Thompson discusses various elements of coding and particularly what the lives of coders are like. Thompson dedicates an entire chapter to artificial intelligence and talks about many things such as the success of an AI at playing the game go using reinforcement learning and a less common search tree (the Monte Carlo search). The chapter features an interview with head of AI at Google, Jeff Dean, and details many techniques such as neural networks. The piece is extremely well researched and uses a highly reliable and knowledgeable source (Jeff Dean) and aligns with general knowledge of the subject, making it valid and reliable. The versatility of application for AI as well as its ability to perform with super-human intelligence is impressive and shows promise for application in all fields, including healthcare. The description of neural networks furthered my understanding of the topic and enabled me to understand the strengths and limitations of such systems, something which is transferrable when analysing the pros and cons of AI in healthcare (making concepts such as racial bias in training data leading to flawed systems easier to understand).

(Tidy and Bonsall 2017). This article describes what AF is, including symptoms and types of AF. Particularly relevant is its description of paroxysmal AF, where symptoms of AF are sometimes present but abate for periods of time, as paroxysmal AF is very common amongst those who have not been diagnosed with AF. The piece is published in a reliable medical cite and has been written by a doctor and reviewed meaning that the content can be trusted. The information presented is also consistent with other reliable sources such as (British Heart Foundation 2019) and (Arrhythmia Alliance 2020), lending more validity to it. The purpose appears to be solely to inform.

(Tison et al 2018). This paper summarises the development of a deep neural network that detects atrial fibrillation using the Apple Watch which achieves a sensitivity of 98.0% and a specificity of 90.2%. This paper is widely accepted and maintains thorough methodology and impressive results, showing the accuracy of the model. Furthermore, it is not the only Apple Watch AI model that has achieved similar results lending validity to its results. The high accuracy of diagnosis shows potential as it enables passive and continuous measurements across a large population.

(Tricentis). The article describes the existence of rule-based expert systems which can be thought of as systems that have had knowledge encoded into them by humans and are static models that can only be changed through human alteration of code. Such systems are well documented and do exist, with one of the first AI computer systems to be developed for the medical domain being a rule-based system (called MYCIN). The piece goes on to compare rule-based systems to learning systems and points out that rule-based systems are advantageous as they do not suffer from the lack of transparency self-learning systems do (known as the "black box" problem). The piece points out that rule-based systems are flawed in some respects as they are difficult to maintain and rely on the information encoded into them being accurate. The information of this article seems to be accurate as it cites multiple sources, such as an image recognition algorithm that was fed poor training data and was unable to perform its task well. In short, all of its points are backed up and valid and thus can be viewed as a fairly reliable source. The idea of black box AI being a serious flaw is something that links into the inherent lack of trust physicians may place in a system or conversely the excessive amount of trust a doctor is asked to place in the computer, even if the computer may be incapable of coping with data outside of the scope of its training sample. This idea of showing what areas an AI is looking at represents a possible way to increase trust in imaging AI.

(Turakhia 2018). This paper estimates that 5.3 million people had AF in the USA in 2009, of which 0.7 million were undiagnosed (13.1%). The paper uses a strong and reliable methodology that can be replicated as the data it is analysing is publicly available. The piece is authored by a range of experts, including an academic form Stanford University's School of Medicine and therefore is trustworthy. As such, I have strong confidence in the accuracy of the results of this paper. This piece is very important as it highlights the great benefits of more successfully identifying AF.

(Turakhia et al 2015). This piece analyses the healthcare costs of those with undiagnosed AF and compares it those with diagnosed AF and finds that "incremental cost burden of undiagnosed nonvalvular AF is $3.1 billion" (in the USA, when compared to those with diagnosed AF). The methodology of this paper is sound and as such I have a high degree of confidence in the findings. Furthermore, this will be an underestimate for the overall economic costs as undiagnosed AF leads to a greater stroke risk which has economic ramifications beyond medical expenditure such as inability to work and poorer quality of life resulting from strokes that induce disability. In short, this shows the massive economic potential of a device such as the Apple Watch as it could have a large economic impact and a large social impact as well.

(Turakhia et al 2019). This science direct journal piece describes the methodology of the Apple Heart Study, a study that makes use of the Apple Watch amongst a group of 400,000 people to scan for atrial fibrillation. It also describes the rationale and benefit behind such a study, highlighting the massive economic detriment of undiagnosed AF as well as the benefits of reduction in stroke risk. The contents are credible as the study was performed by reputable organisations showing that this method was implemented. However, the piece is limited as the study is payed for by Apple which is a conflict of interest. Despite this, best academic practices were clearly adhered to. The large sample size is important to strengthen quality of data although the trail design is limited by the fact that it is not randomised and that the demographic may be skewed towards those who are young (and less likely to have undiagnosed AF).

(Tutorialspoint 2020). This piece provides an overview as to what artificial intelligence actually is and provides an overview of its history, general subsets (such as machine learning and rule-based systems) as well as common applications such as natural language processing and image recognition. The piece appears to be designed to be informative even if it does not stem from a highly reputable source. However, the contents of this tutorial are extremely accurate and aligns with general knowledge around the subject. The history of AI segment is very well researched which lends massive validity to this source. This general overview of different types of AI as well as their strengths is directly transferable to medicine (for example this recurring theme of AI being strong at image recognition is something that transfers to fields of medicine such as mammogram analysis).

(Vanian 2020). This article details the release of OpenAI's first natural language processing system, a bot that can respond to human input and answer things such as trivia questions or perform basic mathematics. The GPT-3 model has over 175 billion parameters. The contents are accurate as this release was widely

reported, the quotes from OpenAI co-founder are accurate and because the product described is available through an application programming interface. The ability of AI to understand and meaningfully respond to human text could prove to be important in seeking to, for example, replace / co-exist with general practitioners. NLP can be used in many parts of health care such as speech bots like Apple's Siri or in analysis of notes taken by doctors to extract meaningful data.

(Walsh 2020). This BBC News report summarises the main points of the Nature article that is used at detecting whether breast cancer is present (McKinney et al 2020). This piece focuses much more on the socio-economic implications of AI and it describes concerns over divulging of sensitive health data to third parties as well as hinting at the fact that there may be problems when such a system is implemented. It also discusses the benefits of the system as it is tireless and is well suited to optimise the current system by replacing one of the doctors that normally analyse such a scan. In this instance, an expert believes that the AI will not lead to a lack of demand for radiologists as there is already a large shortage of them. However, I would argue that this is probably less applicable more broadly and imaging AI in general will lead to far fewer doctors being needed. However, in the very long term, better accuracy and cheaper medical bills can only be a good thing even if there are large social implications to reducing the demand of doctors (such as lack of advancement in medical research and large unemployment levels). This piece is published by the BBC, which is a trusted news organisation which has an agenda of impartiality. The article gives no opinions but instead interviews various experts who give their viewpoints on the potential socio-economic impact of this system. As such, this article is highly relevant to this dissertation.

(Watson et al 2019). This peer reviewed British Medical Journal piece assesses one common issue with AI: its black box nature. It concludes that machine learning algorithm are inherently black box in nature and that for legal, social, and moral reasons, this must be altered. Once more, this article's content is reputable due to the standard of the journal it is published in and the fact that it is peer-reviewed. Furthermore, this problem with the black box and the difficulty to trust a machine that does not justify its answers leading to potentially catastrophic results is echoed across the community as seen in other resources such as (Bender 2019). As such, the content of this piece is accurate and hence the source is valid for inclusion.

(Watson, Whiting and Brush 2020). The British Medical Journal piece talks about the accuracy of COVID-19 tests and how a negative or positive result should be interpreted. The piece references source (Arevalo-Rodriguez et al 2020) and concludes that the between 2% and 29% false negative rate may be an underestimate. It also highlights studies which show that other forms of the COVID-19 test have a greater false negative rate than 29%, which suggests that the tests are at least somewhat flawed. However, whilst this is published in a reputable peer-reviewed journal, the piece is unlikely to be completely accurate as it is based on preliminary and small studies and was written when COVID-19 was a very new phenomenon. However, it does at least show that the COVID-19 tests are not perfect and lends strength to (Arevalo-Rodriguez et al 2020)'s conclusion.

(Williams and Lavizzo-Mourey 2016). Williams and Lavizzo-Mourey. present their view that black people in America are less healthy than other races and cite racial bias and socio-economic inequity as some of the reasons as to why this is. The piece is somewhat opinionated and anecdotal, highlighting individual cases to support their claims. However, their points are backed up by science and they reference various pieces such as a peer-reviewed JAMA piece which finds that racial bias is partly responsible for the worser health state of black Americans. It also mentions a study across the 171 largest cities in the USA that concludes that white people "living in the worst conditions in urban areas – in terms of poverty rates and single-parent households – are nonetheless residing in circumstances much better than those of the average black person.". As a result of this, the piece presents a compelling case for medicinal racial inequity in America and can be trusted, although the piece is also not neutral (i.e. it is clearly arguing solely from the side of racial inequity). However, the science agrees with this piece as the picture it paints is consistent with other studies into racial disparity in healthcare. The fear is that artificial intelligence systems may further this as there are fewer black people than white people in America (potentially leading to software that works better for white people in America), something which has already been seen in facial recognition AI which performs notably worse on people of colour.

(World Medical Innovation Forum 2019). This 2019 panel amongst medicinal AI industry leaders discusses the current state of AI in healthcare and what issue need to be overcome (and how) in order for this implementation to become widespread. Various use cases such as image analysis, extracting meaningful data from notes taken by doctors and general diagnosis are discussed. The piece focuses on a large theme of this dissertation (which is discussed in sources such as (Bender 2019)) and one of the primary problems with implementation of AI into healthcare: its black-box nature. One interesting point raised by Doctor Katherine Andriole is that the black-box nature is still a large problem that must be overcome for widespread implementation to be possible but that techniques such as a saliency map have been successfully developed to somewhat mitigate this. This technology can, for example, show to doctors which features of a patient's image are being used to calculate the decision. These maps have been used to show that, in some cases, AI analyses the exact same features a human doctor would which she says allows for a greater level of trust in the systems. However, all the panellists including her conclude that this alone does not suffice as they feel that if a doctor cannot trust the system, then the patient cannot either. This is however a contentious issue and some feel that the black-box trade-off may be worthwhile given better accuracy.

(YouTube 2019). This introductory video series on Artificial Intelligence, published and created by YouTube, covers a wide range of subjects including how AI functions as well as applications in healthcare. It shows an example of an artificial arm that uses electronic singles from a user and an AI to give the wearer more advanced control of their arm and hand than a typical replacement limb. This is a series designed to entertain and also inform and the series is clearly very well researched as it is published by such a large company and clearly has a large budget. I did not include the source directly as the piece tends to provide a broad overview of each area and as the medicinal aspect was highly experimental (and less suitable to analyse than the breast cancer diagnosis AI as there were less resources available on the "Skywalker" hand). However, the source is still valid and helped me shape and enhance my understanding of the topics and themes in this dissertation.

(Zhou et al 2019) This peer reviewed paper details various types of machine learning techniques and phrases such as convolutional neural networks, deep learning etc. The piece then describes the potential use of these systems in medical imaging such as the diagnosis and detection of liver disease. The paper concludes by highlighting some hindrances to future implementation of AI in healthcare, such as the fact that AI may be good at performing certain tasks but that it lacks the higher levels of awareness and context and thus may be flawed when dealing with complications. The piece is written by a team of academics and peer-reviewed which means that it is safe to conclude that the content is accurate. Furthermore, the content aligns with other resources leading me to believe that this source is valid. It also links into this recurring idea of AI showing potential but not yet being implemented.

[Figure 1] This picture on stackexchange is the result of running an open source script produced by Mark K Cowan. It is a picture of a typical neural network architecture. This neural network architecture matches other common drawings of the structure and hterfore is clearly accurute.

[Figure 2] This image is taken from a tweet by Eric Topol, a verified Twitter user and a renowned American cardiologist. This picture is of all FDA approved AI systems as of January 2019. Due to Topol's expertise in the field, this photo is likely to be accurate and well-researched, particularly as it uses a highly reputable Nature article for the basis of this source. Others have highlighted other AI applications that may also qualify for this list. Some of these examples can be found in the comments of the original post. It is also important to note that some other AI systems are used in healthcare that do not require FDA approval but most of these fall outside of the scope of the dissertation as they do not directly satisfy this essay's definition of medicine. The number of these systems that have already been implemented is also low (World Medical Innovation Forum 2019). Despite, this the systems included are accurate and the number of systems not included are low.

[Figure 3] This is an image in the same tweet as [Figure 2] but this time showing FDA approved AI applications as of April 2019. Unlike, [Figure 2] Topol seems to have compiled the list himself perhaps leading to mistakes. All of the examples listed are accurate (something I have verified myself), although some of the comments on the Twitter post suggest that Topol may have missed a few approvals with one

user pointing out three possible cases that Topol may have not included (although some may argue that the examples mentioned do not strictly qualify for Topol's list). Despite this, Topol has clearly done his research and included all, or the vast majority, of FDA approved healthcare systems. Therefore, this source and [Figure 2] are highly useful to the dissertation as they show the small-scale implementation of AI as well as its rapid growth over a few months. Others have highlighted other AI applications that may also qualify for this list. Some of these examples can be found in the comments of the original post. It is also important to note that some other AI systems are used in healthcare that do not require FDA approval but most of these fall outside of the scope of the dissertation as they do not directly satisfy this essay's definition of medicine. The number of these systems that have already been implemented is also low (World Medical Innovation Forum 2019). Despite, this the systems included are accurate and the number of systems not included are low.

[Figure 4] Figure 4 shows a java application that was coded by the author of the dissertation (Philip Mortimer). This tool helps visualise the performance of a neural network at recognising handwritten digits using the MNIST database. The neural network was also trained and coded by Mortimer. This tool can be accessed via the link provided. As, I produced the piece, I know it is accurate and valid. It helps prove a theme of this essay: that AI is highly effective at image analysis.

[Figure 5] An estimate for the potential economic impact of the Apple Watch is provided in [Figure 5] by combining data from the Apple Heart Study, the prevalence of AF and the economic impact of AF. The mathematics is explained in the source. However, the figures only serve as rough estimates as there are a range of factors that the piece simply cannot account for due to lack of information. The piece is limited by its simplistic methodology but the ability of the Apple Watch to save around $7 (when only looking at healthcare expenditure) per US citizen who has irregular pulse notifications enabled and does not suffer from AF, is an important one. This figure may well be greater as it does not account for potential income lost and a better quality of life. The figures do show the potential of the watch to have a large economic impact even if one should only interpret it as a rough estimate that is probably far off the truth. That being said, I do have confidence that I performed the mathematics correctly and that the methodology is valid (even if it is simplistic) and that its finding of a significant economic impact of the Apple Watch's AF system is an important and valid one.

[Figure 6] This picture shows an example of the Apple Heart App used alongside the Apple Watch. This picture is clearly accurate as it comes directly from Apple and can be verified through a simple Google search. As such the piece is valid and helps provide a sense as to what the technology looks like.

[Figure 7] This picture shows an example of an irregular pulse notification from an Apple Watch and also comes from Apple, clearly making it accurate. This piece is relevant as it helps provide a greater understanding of the technology being discussed by providing a clearer image of how it actually functions.

[Figure 8] This is a neural network trained by the author of this dissertation (Philip Mortimer). All the source code is visible and self-explanatory. The resource is clearly valid and reliable as it functions as intended, achieving an accuracy of roughly 83 percent, a figure which is typical for other systems. All source code was written by the author of the dissertation (Philip Mortimer). Source code: https://github.com/PhilipMortimer100/Tumour-Classification-Using-Machine-Learning (accessed on 30th December 2020).

EPF 4	EXTENDED PROJECT PRESENTATION	

Here is a copy of my script that I used when preparing for my presentation. This was slightly refined through regular practice. I committed this script to memory when performing my EPQ presentation. The script takes just under 15 minutes when performed.

For my presentation, I decided that giving a talk was the best way to convey my dissertation outcome and wider project process. I decided that I would make use of PowerPoint, to create a visual aid that underlines my talk and makes it more effective. I feel that my PowerPoint was effective as it makes it very easy to follow along with the key points of my presentation whilst providing simple visual stimulus that kept the focus of my audience. I explored a number of resources on how to use the technology effectively (such as: https://www.youtube.com/watch?v=6bSOAl1i8bw), with a key take away being that it is important to minimise the amount of surplus text on screen. An effective presentation involves a small amount of important information being displayed in a visually clear format. This involves making use of bold text, images and a background that suits the theme of the presentation. I feel that I have implemented all these tips and mastered this technology very well – creating a PowerPoint that summarises the main points of my presentation in a visually interesting and clear manner that really compliments my presentation. I also made great use of colour to create a visually interesting background that fits very much with the focus of the presentation (AI). I developed many key skills when creating this PowerPoint, including effective presentation of ideas, effective oration and I was able to learn about new technologies.

I feel that my presentation method of a PowerPoint presentation alongside a talk was the best method as a talk is really needed to convey the outcome of my dissertation and project process. Use of a PowerPoint definitely makes my presentation much more understandable, memorable and interesting and hence I feel strongly that this was clearly the best method for my presentation.

EPQ Presentation Script

Slide One:

Hello and welcome to my Extended Project presentation. My presentation is split into two parts: the dissertation outcome and the wider project process.

Slide Two:

Part one: my project outcome.

Slide Three:

My research title is: “To what extent do the use of Artificial Intelligence systems in Medicine contribute to the socio-economic condition of society?”.

My dissertation focuses on Artificial Intelligence, or AI, systems that are used in healthcare. AI systems are computer programs that can perform tasks as or more intelligently than a person. My dissertation evaluates both the social and economic impact of these systems.

Slide Four

An AI technique – known as machine learning - makes use of large amounts of labelled data to create an effective model. These AI systems spot complex patterns in data and use this to perform tasks, such as

image analysis, effectively. As a result of this, AI is limited by the size, quality and accuracy of data provided and can sometimes develop unfounded biases due to atypical data.

Slide Five

For example, I trained a machine learning model to diagnose skin cancer using photos of pigmented lesions (such as moles). My model is trained using around 2000 images of lesions that are labelled as either cancerous or not, and it outperforms dermatologists at skin cancer diagnosis. However, my model is not perfect. As the training images are overwhelmingly from people with white skin, it is quite likely that the model will perform significantly worse on people of colour. This an example of unintended bias that plagues many AI models and shows the real danger of furthering racial healthcare inequity through AI.

I will hand out digital copies of the PowerPoint so please feel free to try out my AI at the following link once the presentation is over.

Slide Six

A survey of industry experts conducted by McKinsey and Company found that the use of AI in healthcare was between exploratory and experimental and that there was a large amount of funding for research into medical AI. Whilst the large amount of research shows the capability of the technology, there are far fewer Artificial Intelligence systems currently used in Medicine.

As of April 2019, the American medical regulator, the FDA, had approved 26 AI systems for use. This number is significantly greater than 3 months prior, when the number was 14. Roughly half of these systems are used in medical imaging.

To assess the overall impact, I will assess the impact of research into Medical AI and of AI systems currently used in Medicine.

Slide Seven

To look at the socio-economic impact of research into Medical AI, I took a deep look at a breast cancer diagnosis system.

Slide Eight

Google's breast cancer diagnosis software was trained on 29,000 mammograms and was found to significantly outperform British and American radiologists and to perform as effectively as two radiologists combined. This is significant given that two radiologists are currently used to analyse a single mammogram in the UK, with the study concluding that AI could be used to eliminate the need for a second radiologist.

Slide Nine

Improved diagnostic accuracy has the potential to save many lives, which is socially and economically advantageous. The reduction in false positives will also help to avoid the significant emotional distress such a result can cause.

Radiologists work for long periods of time and can often get tired. Computers conversely provide instantaneous and consistent analysis.

Such a system would make breast cancer screenings much faster and more cost effective. Faster screenings would enable more breast cancer screenings to be carried out, with early diagnosis leading to far higher cancer survival rates.

Many would argue that it is ethically objectionable for such large amounts of sensitive data to be handed over to companies, although I would argue that data anonymisation adequately mitigates these concerns.

This system is very similar to other AI systems being researched. I conclude that such systems do have a positive socio-economic impact as they encourage research and lead to systems that save lives. However,

the current impact is limited by the fact that research is expensive and that systems such as this one have not yet been implemented.

Slide Ten

To answer my question, I also needed to analyse medical AI systems currently in use. Similar to with researched systems, I decided to focus on one system that paints an accurate picture of all systems.

Slide Eleven

Atrial Fibrillation, or AF, is a heart condition that affects 5 million people in the USA, with around 13% of cases being undiagnosed. A 2015 paper estimates that undiagnosed AF costs around 3.1 billion dollars annually in additional healthcare expenditure – which is partially due to the significantly higher stroke risk amongst undiagnosed AF sufferers.

Slide Twelve

Apple's smartwatch, the Apple Watch, has a clinically accurate electrocardiogram which has been utilised to create software that detects Atrial Fibrillation. The AI system was trained using data from 10,000 AF patients and the software has been approved by the FDA.

Slide Thirteen

A major piece of literature for this dissertation was the Apple Heart Study, a study consisting of 420,000 volunteers who had not previously been diagnosed with AF. The study was designed to assess the accuracy of Apple's atrial fibrillation detection technology, and the large sample size lends high validity to the study's findings. The study found that the software had a positive predictive value of 71%, meaning that 71% of identified cases were confirmed to be AF by additional tests. Using an estimate of AF prevalence in the USA, roughly 77% of the expected cases were identified, showing that the Apple Watch is highly effective.

Slide Fourteen

I calculated that each watch saves an average of 7.83 dollars in annual healthcare expenditure – or around 550 million dollars when applied to the user base of the Apple Watch. It is important to stress that this is a very rough estimate. What it does show is that the AI has an enormous economic benefit.

Slide Fifteen

Improved diagnosis of AF will save and enhance the quality of many lives. It also makes widespread AF screening viable. AI systems like this will lead to more research into the field, which will ultimately save many more lives – an additional socio-economic advantage. However, Apple Watches are expensive which limits their viability as an AF screening tool somewhat.

Slide Sixteen

The benefits of the AF system are applicable to most of the approved systems. I conclude that the overall socio-economic impact of both researched and approved systems is positive. Each approved system has an overwhelmingly positive impact, but the small number of approved systems does significantly limit their current impact. Additionally, social concerns about data privacy and biases in models need to be addressed further to make the overall impact more positive.

Slide Seventeen

Part Two – The project Process.

Slide Eighteen

I conducted a wide range of research into several topics that interested me to find one area that was suitable for my dissertation. I considered writing my dissertation on quantum computing, Artificial Intelligence or the derivation of pi amongst other topics. These topics interested me and were areas with a great deal of research. Eventually, I decided to focus on AI as I felt that quantum computation had too little

research and was too complicated for my project and I felt that there was little scope to present conflicting viewpoints regarding the history of pi.

Initially, my focus was on future applications of AI considering current uses. As the project went on it became clear that the focus on future applications was purely speculative and allowed for little academic analysis, so I decided to focus on current applications. This was tricky as it required me to redraft a significant amount of my work.

Finally, when writing my dissertation, I realised that the scope was too broad for a 5-thousand-word essay and hence I ultimately focused on AI in healthcare. In hindsight, I should have conducted more research into the requirements of the EPQ and the individual fields considered before choosing my initial title. However, I am extremely pleased with the title I ended up with.

Slide Nineteen

To ensure a successful project, I came up with a comprehensive list of aims and objectives. I came up with four broad aims and three or four objectives to achieve each aim.

My first aim was to thoroughly answer my dissertation question. To do this, I decided that: I needed to explain what AI is, present and explain the socio-economic impact of medical AI and take all viewpoints into account to reach a valid conclusion. I feel that this first aim was critical to the success of the project and that the objectives cover the dissertation requirements thoroughly. I feel that I have successfully achieved all of the described objectives, performing particularly well at presenting clashing viewpoints and using a range of resources to reach a conclusion. In hindsight, I would also have added an objective that focuses more explicitly on talking about the socio-economic impact of research into medical AI.

Click Again

My second aim focuses on using a wide range of valid resources to ensure a comprehensive paper. I set a target of using 100 resources. On reflection, choosing an arbitrary number of resources was a poor objective and aiming “to use a large number of valid resources” would have been a more appropriate objective. However, I did still meet my objective as I analysed about 120 sources, which led to my dissertation painting a full and clear picture on the issue. My next objective focuses on evaluating each resource to assess its validity. This was a really important objective, as I came across a number of opinionated and invalid resources that could have harmed the accuracy of my dissertation. I have clearly achieved this objective as I have analysed all sources in great depth. My final objective focuses on using a wide range of resources. In hindsight, this objective was a poor one as certain types of resources were clearly far more important than others. My project focuses heavily on peer-reviewed academic papers, which are far more valid and useful than newspaper articles for example. However, I did use a wide range of resources, with books, podcasts, videos, newspapers and journal entries all being assessed.

Slide Twenty

I aimed to create a comprehensive plan to enable success in my project and meet appropriate deadlines. I decided that I wanted to create a list of sub questions that needed to be addressed in order to answer the overall question. I did this in my initial plan but ended up not making use of these questions. I composed a mental list of sub-questions which were helpful in reaching my conclusion, but I feel that I should have done more research before composing the sub-questions initially. My next three objectives focus on creating an appropriate time management resource to plan out my entire project. I certainly succeeded in this as I made a comprehensive plan documenting what I would need to achieve and when by. In the end, my plan was largely ineffective although this was due to the COVID-19 pandemic leading to unforeseen changes.

Click Again

My final aim focuses on developing a wide range of skills needed to write my dissertation. My digital literacy skills were vital as most of my resources were accessed online. I am glad I developed my understanding of advanced search techniques and use of Google scholar as these skills helped me identify appropriate medical research papers, such as the Apple heart study. My next objective focuses on secondary source

analysis, another skill which I developed and was vital when analysing the validity of all resources used. The CAP analysis technique was invaluable and hence this objective was met and appropriate. My final objective was to research Harvard referencing, the referencing technique I ultimately used in my project.

Overall, I feel that I met all of my aims and objectives, although some of the objectives for Aim 3 proved to be ineffective in the end.

Slide twenty-one

After researching time management techniques to use in my project plan, I settled on using both a Gantt chart and table. I did this as a Gantt chart, which is pictured, is very useful for time management whilst a table allows for a detailed breakdown of what I need to do to achieve each milestone. My plan was highly detailed and well laid out, breaking down when each milestone needs to be achieved by and what needs to be done in order to reach the milestone.

However, after meetings with my supervisor and actually writing the dissertation, the focus of my project shifted significantly. This led to my original plan being ineffective. Furthermore, the rigid nature of the self-imposed deadlines was unrealistic and ineffective as I personally work more effectively with fewer deadlines that require larger amounts of work. I produced a rough outline of my essay, which was a foolish idea as I had not performed enough research into the field to be able to do this accurately. In hindsight, I would have created a more flexible and less detailed plan that outlines what roughly needs to be done without being so specific that it would likely change over time.

The COVID-19 pandemic also changed all my deadlines as my way of life was significantly altered. I feel that no plan would have been effective as the pandemic was unforeseeable and impacted every deadline. Having said that, I think that my plan was detailed and well-made and would have probably been very useful had it not been for COVID.

Slide twenty-two

Throughout the dissertation, I had to make many key decisions – such as deciding whether certain sources are valid. As mentioned previously, my title changed several times over the course of the project. At one point, I had written most of my dissertation when I realised that the scope of the question was too broad to be covered in 5000 words. This should have been mitigated by better planning in hindsight. However, I ultimately decided to rewrite the essay and change the question as I felt that spending more time on the essay was worthwhile. I am confident that I made the correct decision as my final essay is of a very high standard and much more thought out. Through source analysis, I rejected numerous resources and acknowledged the shortcoming of others which lead to a much fairer view of the socio-economic impact of AI. Many sources, particularly video resources were hyperbolised and poorly researched.

My time management skills were honed throughout the process as I had to meet various deadlines and ensure that I was able to spend enough time to write a high-quality paper and analyse over 100 sources thoroughly. My critical thinking skills also improved as I had to analyse valid resources that often said conflicting things and draw a reasonable conclusion from these.

Slide twenty-three

I am very satisfied with the outcome of my project, as I feel that I have produced a very strong dissertation that accurately and comprehensively covers the socio-economic impact of medical AI. I feel that I have presented all viewpoints fairly and used these to draw a valid and strong conclusion. I used a very wide range of reliable resources to reach my conclusion, with over 100 well-researched pieces contributing to my findings. Whilst I feel that my dissertation outcome is strong, I also feel that my project plan was ineffective and that I spent far too much time on areas that I ended up redrafting as they were unsuitable. All of my EPF forms and dissertation are at a standard I am very happy with, although I feel that more research and forethought would have enabled me to waste less time and reach the same high-quality outcome.

Slide twenty-four

Thank you for listening to my presentation, I would now like to open the floor to any questions.

PowerPoint

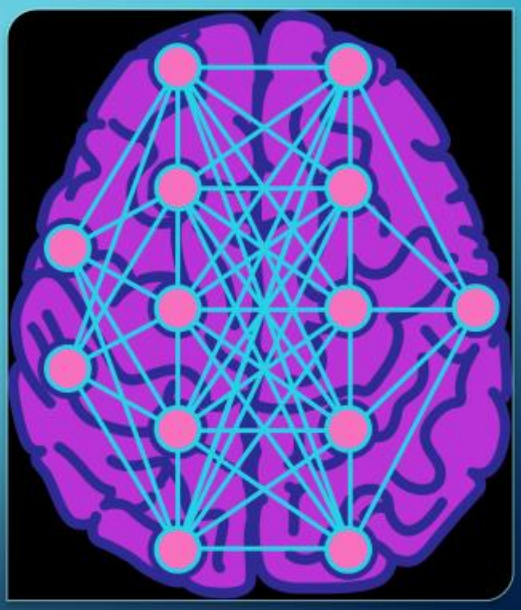
Here is the PowerPoint I used when giving my presentation.

TO WHAT EXTENT DO THE USE OF ARTIFICIAL INTELLIGENCE SYSTEMS IN MEDICINE CONTRIBUTE TO THE SOCIO-ECONOMIC CONDITION OF SOCIETY?

- Artificial Intelligence (AI) – computer systems that perform tasks as well as humans.
- My dissertation focuses on the overall social and economic impact of AI systems in healthcare.
- Medical AI can be divided into two categories: systems that are in the **research phase** and systems that are **currently used** by medical professionals.

STRENGTHS AND WEAKNESSES OF AI

- Machine learning systems find underlying patterns in data.
- AI is effective at image analysis.
- AI systems are limited by the accuracy, quality and size of data provided. This can lead to **unintended biases**.



EXAMPLE

- My model was trained on 2000 images of pigmented lesions.
- Outperforms dermatologists at skin cancer detection.
- Model will perform worse on people of colour.
- Try it - https://github.com/PhilipMortimer100/Tumour-Classification-Using-Machine-Learning

PREVALENCE OF MEDICAL AI

There is **lots of research** into Medical AI, but **little implementation.**

26 approved AI systems.

Roughly half of these systems are used in medical imaging.

Quantib	Medical imaging (MRI)
CureMetrix	Medical imaging (Mammography)
BrainScope	Concussion Assessment (multi-modal)
Apple	Atrial fibrillation detection
Aidoc	Medical imaging (CT scan)
iCAD	Medical imaging (Mammography)
Zebra Medical	Medical imaging (CT scan)
Bay Labs	Medical imaging (echocardiogram)
Neural Analytics	Device for Paramedic stroke Diagnosis
IDx	Diabetic retinopathy diagnosis
Icometrix	Medical imaging (MRI)
Imagen	Medical imaging (X-ray)
Viz.ai	Medical imaging (CT scan)
Arterys	Medical imaging (MRI and CT)
MaxQ-AI	Medical imaging (CT)
Alivecor	Atrial fibrillation detection
DreaMed	Diabetes treatment decision
Arterys	Medical imaging (MRI)
Empatica	Warning of seizure risk
Subtle Medical	Medical imaging
Cognoa	Autism diagnosis
Healthy.io	Urinary tract infection diagnosis
Excel Medical	Remote monitoring
FibriCheck	Atrial fibrillation detection
ScreenPoint Medical	Medical imaging (Mammography)
SyncThink	Eye movement disorders

RESEARCH INTO MEDICAL AI

BREAST CANCER DIAGNOSIS SYSTEM

- Trained on 29,000 mammograms (an X-Ray image of the breast).
- Had 1.2% fewer false positives and 2.7% fewer false negatives than British radiologists.
- This AI system performed as effectively as two radiologists combined.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Health

AI 'outperforms' doctors diagnosing breast cancer

Fergus Walsh
Medical correspondent
@BBCFergusWalsh

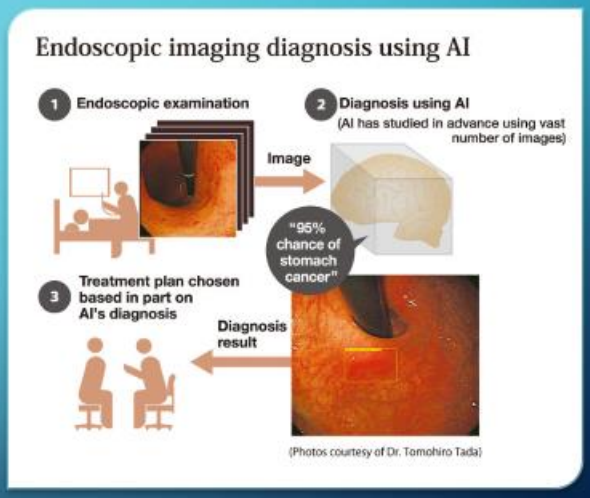
2 January 2020

SOCIO–ECONOMIC IMPACT OF SYSTEM

- Potential to save many lives.
- AI doesn't get tired – more consistent analysis.
- Would address shortage in radiologists.
- Research like this will lead to accurate AI systems being used widely in healthcare in the future.
- Ethical concerns about access to sensitive health data. Can be addressed by anonymisation.
- This system has not been implemented yet.
- Research is expensive.
- This system is similar to other systems currently being researched.

AI SYSTEMS CURRENTLY IN USE

- **Low** number of AI systems currently in use.
- To assess the overall impact, I decided to focus on a typical system.
- This approach was justified as the number of systems in use is low and as these systems are all similar in impact.

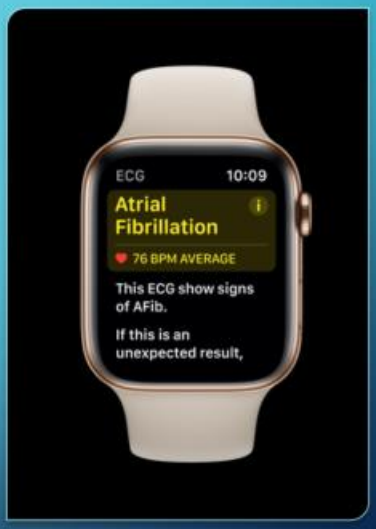


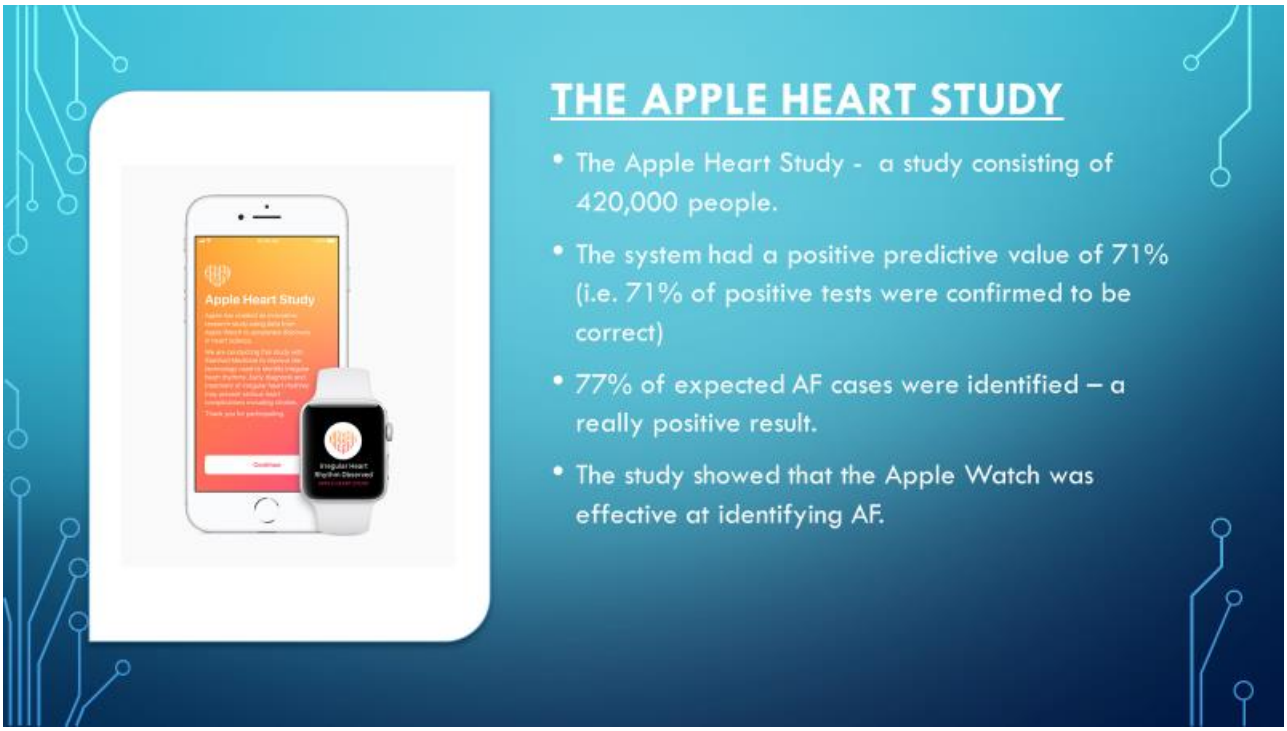
ATRIAL FIBRILLATION DETECTION

- Atrial Fibrillation (AF) is a common heart condition that affects 5 million people in the USA.
- Around 13% of cases are undetected.
- Undiagnosed AF suffers have a very high stroke risk.
- Undiagnosed AF costs $3.1 billion in additional healthcare expenditure in the USA.

ATRIAL FIBRILLATION DETECTION USING THE APPLE WATCH

- 70 million Apple Watch Sales.
- The Apple Watch has an electrocardiogram.
- 10,000 AF patients were used to train an AF diagnosis system for the watch.
- This system was approved by the FDA and is now a selling point of the device.





THE APPLE HEART STUDY

- The Apple Heart Study - a study consisting of 420,000 people.
- The system had a positive predictive value of 71% (i.e. 71% of positive tests were confirmed to be correct)
- 77% of expected AF cases were identified – a really positive result.
- The study showed that the Apple Watch was effective at identifying AF.

SOCIO-ECONOMIC IMPLICATIONS OF APPLE HEART STUDY

- On average, each Apple Watch sold saves **$7.83** in healthcare expenditure in the USA. Applied to the 70 millions sales so far, the Apple Watch has the potential to save **$550,000,000.**
- This number is only a **rough estimate**.
- The massive economic benefit of this AI system is self-evident.

SOCIO-ECONOMIC IMPLICATIONS OF APPLE HEART STUDY

- AF screening can be rolled out to a large group of people.
- Enhances the quality of and save many lives.
- Millions of dollars will be saved – due to reduction in healthcare expenditure and a longer and healthier life.
- The promise of the technology will lead to development of other effective systems in AF and other areas.
- The Apple Watch costs about £200, making it unsuitable to solely use as an AF monitoring device.

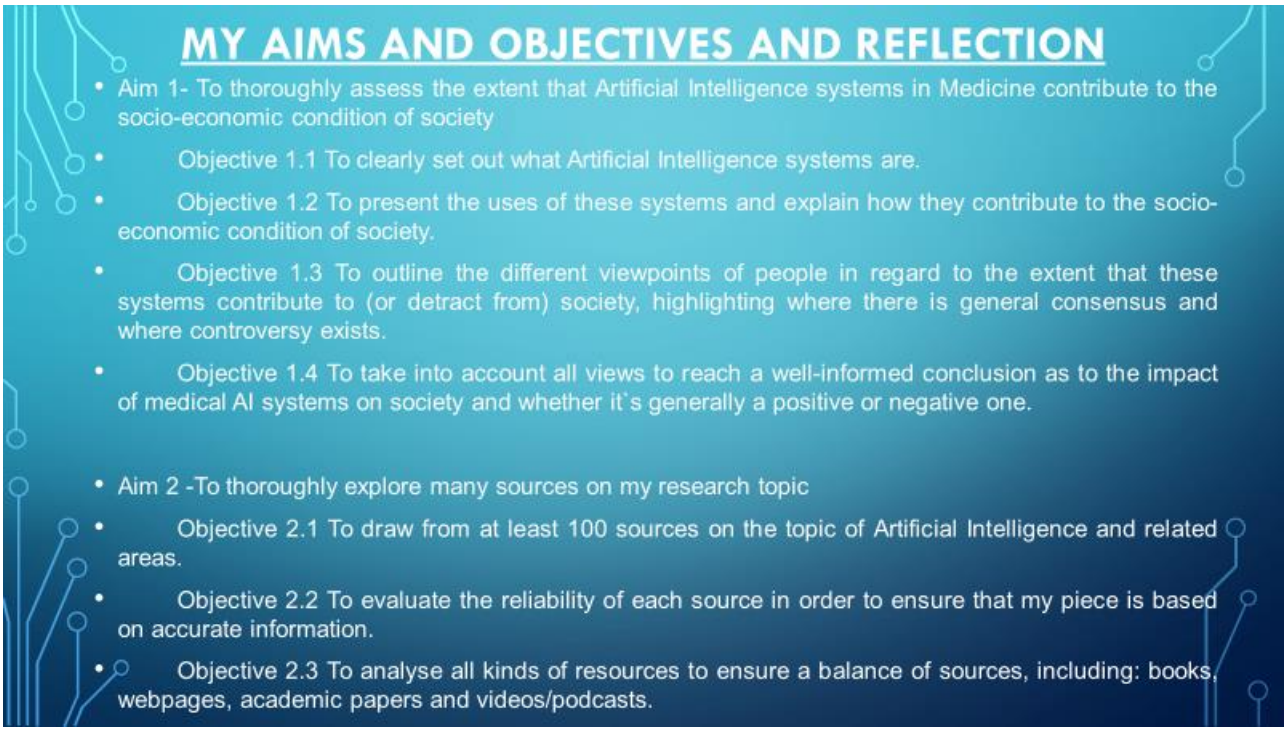
CONCLUSION

- Both research into medical AI and actual use of medical AI have an overall **positive** socio-economic impact.
- I conclude that the impact of each individual approved system is very positive, but that **the overall current socio-economic impact of AI in Medicine is quite positive.**
- The biggest limiting factor is that so few systems have been approved.

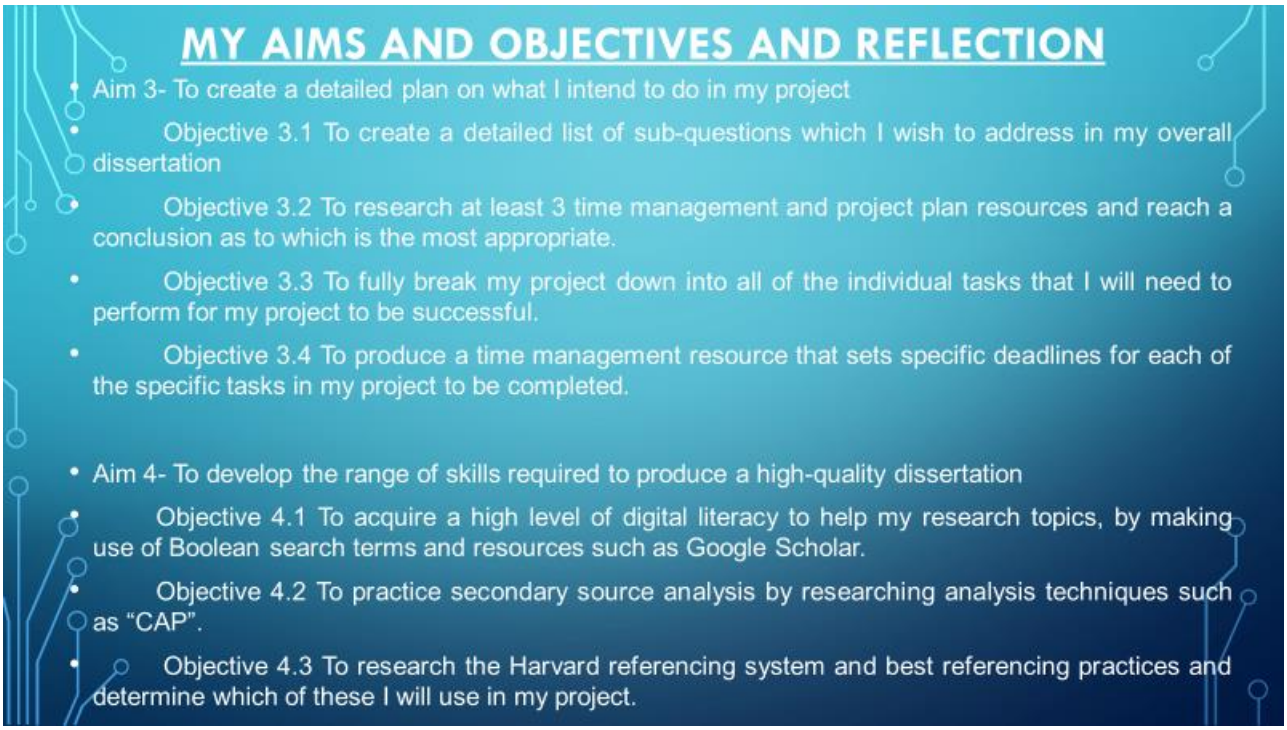
PART TWO – PROJECT PROCESS

HOW I CHOSE MY DISSERTATION TITLE

- I considered six general topic areas.
- I choose to assess at the potential future developments of AI given its current uses.
- I redrafted my question multiple times. I changed the focus to **current** applications.
- When writing, I narrowed the scope further to only focus on AI in healthcare.
- My actual question: "To what extent do the use of Artificial Intelligence systems in Medicine contribute to the socio-economic condition of society?"



Note: this slide makes use of animation. Initially, only Aim 1 and its related objectives are visible. Once I click my mouse, the other part of the PowerPoint also becomes visible. This was done to make the amount of information on screen more manageable.



Note: this slide makes use of animation. Initially, only Aim 3 and its related objectives are visible. Once I click my mouse, the other part of the PowerPoint also becomes visible. This was done to make the amount of information on screen more manageable.

PLANNING DISSERTATION

- Researched multiple planning methods and settled on using a Gantt Chart and table.
- My plan was detailed but significantly altered through actually writing the dissertation.
- COVID-19 meant deadlines changed significantly.
- My plan was well-produced but ultimately ineffective.
- I would make my plan more free-form if I had to do it again, but I also feel that no plan would have worked due to the unforeseen impact of the pandemic.

PROBLEM SOLVING AND SKILL DEVELOPED

- I started writing my dissertation on overall AI use and came to a point where I realised that the project would be too long. I had to decide whether I should start over with a more focused question or not – **problem solving skills developed**
- There were lots of inaccurate and speculative resources on AI, it was difficulty to decide which resources were reliable. To do this, I researched "CAP".
- Developed time management skills.
- Critical thinking skills.

Presentation Records should include:

- Copies of presentation (slides, etc.)
- Speaking notes/materials

Note:

1. *A copy of the presentation should be included separately.*
2. *Screenshots of the speaking notes/materials may be pasted into this document - additional pages should then be inserted, as required.*

EXTENDED PROJECT

Section B
Supervisor Records

This section should include:

- ***Extended Project Presentation Witness Statement***
- ***Supervisor Final Assessment Mark Sheet***
- ***Internal Standardisation Form***
- ***Where appropriate, written statements from relevant named individuals supporting the learner when the Extended Project is based outside the learner's centre***

EPF 5	EXTENDED PROJECT PRESENTATION WITNESS STATEMENT	

Learner Name:	**Learner No.:**
Centre Name:	**Centre No.:**

*Note: Records are to be completed by Supervisor and comments on the witness statement should be directed to the moderator. Supervisors must record **in detail** how the student was able to make a presentation of their findings and conclusions by selecting a range of communication skills, and how they understood the principles of evaluation and review in relation to the planned outcome and own learning performance. Please expand boxes as necessary.*

Individual Presentation

Assessment of Presentation

Criteria	Coverage	Comments	Fair	Good	Excellent
1. Length of presentation	10-15 minutes with additional Q & A Session		N/A	N/A	N/A
2. Delivery of presentation	Clarity of speech, volume and tone of voice and engagement with audience (e.g., eye contact, rapport, audience inclusivity				

Criteria	Coverage	Comments	Fair	Good	Excellent
3. Content of presentation	(a) Aims and objectives				
	(b) Range of resources used				
	(c) Skills developed				
	(d) Problem solving and decision-making				
	(e) Description, evaluation and review of outcome				
4. Materials used	(a) Visual aids				
	(b) Any other tools used				

Any additional comments:

Question & Answer Session

*Supervisors are required to record **in detail** how the student demonstrated knowledge of their project and how they responded to a series of questions (not previously shared with the student).*

Supervisor signature: _____ Date: _____

EPF 6	EXTENDED PROJECT SUPERVISOR FINAL ASSESSMENT MARK SHEET	wjec cbac

Learner Name: _____ **Learner No:** _____

Project Title: _____

AOs	Learning Outcomes/Assessment Criteria	Max. Marks	Supervisor Marks		Supervisor Comments
AO1 Manage (20)	**LO1** - Identify a topic and its rationale, design a project. **(10)**	10			
	LO2 - Produce a project plan and carry out the project to achieve objectives. **(10)**	10			
A02 Use Resources (20)	**LO3 -** Conduct research, using, selecting and applying a range of resources relevant to the outcome and acknowledging resources. **(10)**	10			
	LO4 - Interpret and analyse information/data and demonstrate understanding of links and connections within the complexities of the outcome. **(10)**	10			
AO3 Develop and Realise (40)	**LO5 -** Be able to select and use a range of skills, including new technologies where appropriate, to reach critical decisions. **(20)**	20			
	LO6 - Be able to produce a planned outcome and realise the project in its entirety. **(20)**	20			
AO4 Review and Communicate (20)	**LO7-** Make a presentation communicating the findings and conclusions from the project outcome in an appropriate format. **(10)**	10			
	LO8 - Demonstrate understanding of principles of evaluation in reviewing planned outcome and own learning and performance. **(10)**	10			
	TOTAL	**100**			

Any other comments _____

Supervisor signature: _____ **Date:** _____

CENTRE INTERNAL STANDARDISATION FORM

Learner Name: _____ **Learner No:** _____

Project Title: _____

AOs	Learning Outcomes/Assessment Criteria	Max. Marks	Supervisor Marks	Internal Moderation Marks	Comments (when changes are made to supervisor marks)
AO1 Manage (20)	**LO1** - Identify a topic and its rationale, design a project. **(10)**	10			
	LO2 - Produce a project plan and carry out the project to achieve objectives. **(10)**	10			
A02 Use Resources (20)	**LO3 -** Conduct research, using, selecting and applying a range of resources relevant to the outcome and acknowledging resources. **(10)**	10			
	LO4 - Interpret and analyse information/data and demonstrate understanding of links and connections within the complexities of the outcome. **(10)**	10			
AO3 Develop and Realise (40)	**LO5 -** Be able to select and use a range of skills, including new technologies where appropriate, to reach critical decisions. **(20)**	20			
	LO6 - Be able to produce a planned outcome and realise the project in its entirety. **(20)**	20			
AO4 Review and Communicate (20)	**LO7-** Make a presentation communicating the findings and conclusions from the project outcome in an appropriate format. **(10)**	10			
	LO8 - Demonstrate understanding of principles of evaluation in reviewing planned outcome and own learning and performance. **(10)**	10			
	TOTAL	**100**			

Supervisor signature: _____ **Date:** _____

Internal Standardisation signed off by: _____ **Date:** _____