Cardiff University

Final Report

Mathematical e-Learner for Young Adults with Down's Syndrome

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Abstract

The main purpose of this project is to introduce a mathematical e-learner to users with Down's syndrome (DS) that is both simple to use and unpatronizing. Currently there is a minimal amount of e-learners readily available for people with learning difficulties; narrow that field to a young *adult* and the options are even less. Society appears to presume that an individual with a disability will exhibit childlike behaviour. This has often resulted in e-learners being designed with inappropriate criteria and realistically more suitable for children.

People with DS struggle to understand and apply mathematics. This is especially frustrating when the number of day-to-day tasks completed by utilising mathematical skills are considered: one of the main tasks being shopping. Independent living for people with learning difficulties is becoming more accessible, and with that the need to improve these mathematical abilities for such tasks as shopping becomes more imperative [1].

However, it is not a lack of ability to learn that is an issue, rather than the process by which these individuals learn. Currently, there are no e-learners available that have been carefully designed with the needs and learning profile of a person with DS solely in mind. Therefore, by completing this project, the aim is to create an e-learner that is easy to use, understandable, stress-free and age appropriate for an adult with DS. One that will enable users to improve their mathematical ability at their own pace without patronising or belittling their intelligence.

To gain better insight into the current market of e-learners and the extent of their usability (or lack thereof) the participants (young adults with DS) were asked to use five pre-existing e-learners. This enabled in-depth interviews to observe and question how the participants coped with the diverse designs, interfaces and functionalities. From this, the fundamental issues in current e-learners could be identified, allowing this projects' end-prototype to eradicate them from its design. The observations also allowed for features that the participants found easy to be recognised, and then emphasised or improved upon in the end-prototypes design. Once these requirements had been gathered the implementation of the e-learner prototype could begin. After the implementation was complete, test cases and end-user testing were conducted. The testing found that most of the requirements were achieved and could validate the success of the project. The e-learner was well-received and the creation of an e-learner suited to the participants specific needs and learning profile was reflected in an evident improvement in their ability to understand and operate the e-learner.

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1 Introduction

1.1 Project Purpose

Managing personal finances and performing quick calculations can be an intimidating task for most people. From personal experience of volunteering with children, teens and adults with learning difficulties, mainly Down's Syndrome (DS), it became apparent that this challenge can be even more distressing for them. Over the years this led to the realisation that people with DS often struggle to understand and apply mathematics in their day-to-day lives. As stated by Sue Buckley: “understanding number concepts and basic mathematical skills is important for many everyday activities in modern societies. Little is understood about the numeracy abilities of people with Down syndrome. At present, it appears that numeracy is an area of relative difficulty and that progress with more complex mathematical understanding is slow” [2]. This becomes an even bigger issue when you consider the increasing demand for assisted living and general independence [3]. Through research a project called POSEiDON was discovered, and through their own research they found that “more or less all interviews show clearly, that the wish to be more self-dependent and autonomous (for people with DS) is very strong” [4]. If people with DS could handle their finances with little assistance, the reality of achieving this autonomy could become more attainable. Therefore, the hope is to a create a simple and effective mathematical e-learner that the intended audience can use easily, with maximum operability and appropriate communication. One which will allow them the opportunity to develop their mathematical ability at their own pace. The scope of this project precludes the ability to focus on all learning difficulties and across various ages, as these variables necessitate vastly differing requirements. Therefore, the project focuses specifically on young adults with DS.

It was initially intended for the e-learner to include numerous pages; each focussing on a different area of mathematics: addition, subtraction, multiplication and a page designated to money specific scenarios. However, the decision on whether to create a varied e-learner or a more focused one will be finalised after research and requirement gathering are completed. This decision is due to the possibility of opposing wants and needs or high demand for one specific area.

The e-learner will be aimed at young adults with DS. This target audience was selected as there is a tangible issue in terms of available e-learners that are free, age appropriate but still understandable for young adults with DS. Younger generations have access to appropriate online games and quizzes to aid in their learning, as most e-learners that accommodate the needs of people with DS are aimed at children. Although the content and communication for most available e-learners may benefit young adults with DS, the actual targeted demographic of children is often obvious through the interface design. This can be extremely undermining for adults to use. As the target audience for this project is young adults, and therefore they are no longer in school, this e-learner is an optional learning experience which will be made more appealing if the game is fun and accessible. As many young people are using electronic devices an online application seems the most appropriate way to ensure maximum usage. Through personal volunteering experience it has been

observed that older generations are not as computer literate as young adults, due to this operating the computer could hinder their learning experience. Consequently, at least one of the participants will be above the age of 30, providing true validation of this theory.

1.2 What I Hope to Learn

My main hope is to become more aware and open-minded on how to design applications and other tools. I hope to do this in general for day-to-day design whilst simultaneously being conscious that there are people out there who have specific requirements. This awareness will allow me to cater any future designs to the majority of people, as quite often bad design is down to ignorance of people's needs.

Through this project, I can broaden my own understanding of the struggles people with learning difficulties face with day-to-day tasks that others take for granted. This will expand my awareness and make me more conscious in the future when I am creating the design or functionality of a product. Quite often people with learning difficulties have the capacity to understand as much as anyone else. However, due to lack of time, they are not given the opportunity to learn at their own pace and prove their learning to others. I hope that through this project I can determine what design and usability features better assist people with DS to learn. Through that understanding I can use the knowledge to create a mathematical e-learner that will engage and encourage their learning.

1.3 Aims and Objectives

The fundamental goal of this project is to develop a mathematical e-learner that people with DS can use at ease: one they find intuitive and do not struggle to understand or operate. It should help them to improve and develop their mathematical abilities, whilst simultaneously creating a stress-free environment. As with any implementation it is not possible to fulfil every single person's requirements. However, the aim is to produce as little conflict as possible; ensuring that the functionality and design accommodates the needs of all users.

Should the project deviate from the initial plan, below are the aims and objectives that are deemed essential to achieve for the project to be successful in reaching the core goal.

- Research into DS: common conditions, learning methods and communications that could help develop the requirements.
- Research into pre-existing e-learners that could highlight requirements and potentially provide design or functionality ideas.
- Gather requirements directly from the intended users.
- Learn whether a simple mathematical, financial or mixed e-learner would be more beneficial (requirement gathering).
- Based on the aforementioned requirements, build a set of functional and non-functional requirements.

    - These will be labelled as essential or desirable requirements. Essential requirements are those which need to be met and desirable are the requirements that are not necessary but would be a welcomed addition.
- Explore the potential tools and/or languages that can aid in the implementation of the e-learner.
- Design and implement at least one prototype of the e-learner.
    - This prototype will need to include all the essential requirements identified in the previous objectives and as many of the desirable requirements as possible.
- Conduct at least one round of end user testing for the first iteration of the prototype to ensure that requirements are met and the project is successful.
- Analyse the end user feedback.
- Reflect on the project and evaluate how it could have improved and how it could be developed further.

1.4 Approach

Research will be conducted to ensure maximum knowledge is obtained surrounding common learning difficulties and the learning profile of people with DS. The findings, from educational experts, will guide the development of the e-learner prototype, making it appropriate for the educational needs of the users. Suitable, pre-existing e-learners will be used in the interviews. The participants will be requested to use these e-learners so that the observations can take place, allowing for the identification of which elements they do and do not struggle to use whilst operating them. This will allow for the identification of what should and should not be incorporated into the e-learner prototype and from these observations a set of formal requirements will be produced. These requirements will be separated into functional and non-functional requirements and each individual requirement will be labelled as either essential or desirable. The functional and non-functional requirements will be utilised to aid in the creation of the prototype design. This design can then be used throughout the implementation as a guide on what the e-learner should do and look like.

If all the essential and most the desirable requirements are achieved, the project can be deemed as a success. To ensure these requirements have been attained they will be tested through a combination of test cases and end-user testing. A minimum of one, if not multiple, phases of end user testing will be conducted to judge the success of the e-learner. This should create an iterative approach so that the e-learner can be continually improved upon until it is at a common level of acceptance. Due to the timescale, the project may be restricted to one phase of end-user testing but any feedback will be recorded as a future improvement.

1.5 Risk Assessment

An extensive risk assessment has been carried out to provide the opportunity to pre-empt any potential issues, and mitigate them as early as possible. [refer to Appendix 1.]

2 Background

2.1 Research

There was little obtainable research surrounding the learning profiles of people with DS. There were many websites and studies, all of which are referenced throughout this report, that reached unanimous conclusions and recommendations on teaching a child with DS. The common recognition was that many people with DS suffer from poor hearing and/or sight. This would require audio assistance and larger text being incorporated into the system to aid those who are visually impaired. Visual aids were an undisputed recommendation when teaching someone with DS. People with DS can have difficulty remembering what they have been told verbally - they have a "short-term memory deficit" particularly with verbal learning and processing [5]. Visual aids allow them to make connections and process what they are hearing or reading at a more understandable level [6]. The majority of the research was outdated, written from mid-2000, and some websites/studies were using sources from 1960-80. This demonstrated that the learning profile of people with DS and how to adapt teaching methods to suit their profiles and improve their learning, is obsolete and a study that definitely needs revisiting.

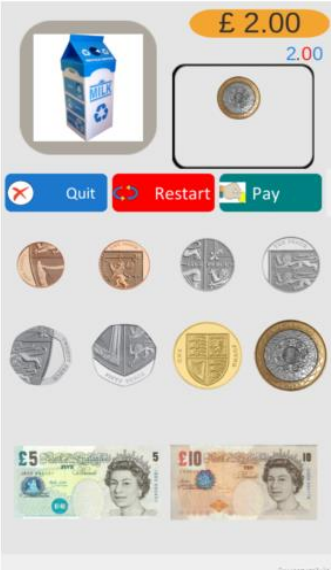
The majority of the research found was based around sensory impairments, such as hearing and vision. Although this was useful and will affect the design, it did not provide much insight into the level of interaction and communication required. It became abundantly clear that visual aids were an essential part of the learning process for people with DS. However, additional findings were sparse and there is an obvious, substantial knowledge gap which this project will begin to address within the investigations.

2.2 Pre-existing Models

During the research it became apparent that there was a severe lack of systems to accommodate for people with DS, especially those above primary school age. Only one current system was found which was designed specifically for people with DS, but it was aimed at those aged 1 year to "adults with learning difficulties" [7]. This would be demeaning to anyone of a post-pubescent age to use; an adult should not have to use a system designed for a child, even if they do require similar assistance. The fact that it was the only system easily and freely available for users with DS was disheartening, and emphasised further the importance of this project.

In 2007 a project named POSEiDON became public. Its target audience was also people with DS but it focussed more on travel assistance rather than financial building skills – skills that will improve the users' ability to understand, calculate and handle money. A simple money managing application was also created and demonstrated. However, from the images provided it does not appear to be very advanced or enjoyable [8].

Figure 1: POSEiDON – Money Application



From the above image, the game looks simple and slightly depressing; there is an obvious lack of colour and no realistic scenario or process to the game. It is simply a picture of an item with a price, and you pay the money. Without playing the game, the image projects the impression that there would be little interactivity which could hinder the engagement.

The POSEiDON project is not yet complete and so none of the products are available to the public. This meant that personal research could not be conducted. However, an explanation was provided:

"The shopping list reminds the users which products to buy. The app also contains a virtual wallet with the money needed to buy the products. When the users tick the products they find and want to buy, the total price is calculated. When the users press "pay" in the app, the amount of money in the virtual wallet decreases and the app suggests which coins and notes they should pay with" [9] .

The explanation is slightly confusing and overly complicated. It seems to be aimed more at increasing independence through familiarising the shopping experience. It also differs from the aim of this project which is to create a user-friendly and enjoyable e-learner that encourages the participants to *want* to develop their mathematical skills. Although the project explained POSEiDON's intentions and demonstrated their progress, it is a product that has not yet been released and therefore it could not be included as one of the pre-existing e-learners in the interviews.

The search for available pre-existing mathematical e-learners was successful (to learn more about the e-learners see section 7.4). However, none of these had the target audience of young adults with DS and so, expectedly, contained many usability and design flaws for the participants. These issues will be highlighted further within section 8 - 8.3.2 of this report.

3 Ethics

As the project revolves around young adults with DS, ethics were an imperative factor to consider. Ethical approval was an undoubtable requirement to complete before the project could truly begin. To guarantee ethical approval for the project, it was required that the compulsory course "Research Ethics 1: Research Governance" be completed. This course encouraged reflection on the project objectives and resulted in consideration on factors that hitherto, had not been thought of. Consequently, below are a list of precautions and explanations to demonstrate and justify the ethical considerations and decisions:

3.1 First Planning Stage

The project's purpose is to create a user-friendly e-learner that fits the participants' specific usability, design and functionality needs. As such, this should enable people with DS to improve their mathematical skills, focussing on finances.

To gather the main requirements of the e-learner, participant interviews will be conducted. During these interviews a series of questions will be asked to help solidify and support the research findings from pre-existing articles. The interview is essential as this type of e-learner has not been previously developed, meaning research from previous studies is outdated or slightly irrelevant to this project scenario. The projects personal investigation will aid in ensuring that the e-learner created is functional for its intended audience.

The methods with which the participants will be interviewed have been carefully selected to accommodate for the fact that the candidates have DS. An 'Ice-Breaker' and 'Thoughts on Mathematics' section have been included to allow the candidates to get familiar with the interview environment and arithmetic-focussed conversation. Once the interviews are completed, the observations can begin. The candidates will interact with pre-existing e-learners and voice their thoughts and feelings throughout. The observations will accommodate the fact that the participants sometimes struggle to explicate their thoughts and opinions. Therefore, observations on body language and mannerisms will help in understanding their struggles, as well as highlighting when assistance is required in helping them articulate their thoughts with the relevant prompts and/or questions. This will prevent any unnecessary angst or stress of the participants.

3.2 Selection of Participants

The participants selected to partake in the interviews range in ages, abilities and past mathematical experience. The reason for doing this was to allow for the small sample (three people) to reach a wider demographic. By using this diverse range of characteristics, the requirements gathered for the e-learner are improved as they are from varying perspectives, abilities and situations; ensuring that the e-learner will be representative and beneficial to the majority of the target audience. The method for selecting the participants

was purely elimination. Through already established relationships with the participants, their ages, abilities and backgrounds are already known. Therefore, recruiting participants who met the various criteria was made easier, more so as there was an awareness of who would be available for interviewing (e.g. one man was a great candidate, but is currently touring the country with a theatre group and therefore would be unavailable).

3.3 Requesting Consent

All participants will be made aware that their participation is voluntary. This will prevent any unnecessary pressure and make the participants feel more comfortable in 'passing' any questions or activities that they do not wish to answer or do. Written consent from the participants will be obtained. However, due to the interview being a combination of both questions and observations and recorded both visually and verbally, consent for all interview methods and techniques will be required. These three factors: being questioned, being observed and being recorded, will all be stated clearly within a single consent form. As the participants have learning difficulties, the main aim was to maintain concise, simple and easy to understand communication throughout the project. Consequently, a pre-existing consent form that follows these requirements has been selected to prevent any miscommunication in the expectations of and for the participants.

The participants will be made aware verbally and within their written consent form that they can 'pass' (i.e. say no/refuse) when answering a question, participating in an activity or if they decide they no longer want to partake in the interview all together. All participants, and their parents, were asked verbally if they would be willing to participate in the interviews a minimum of a week before the interview took place (and the written consent was signed). This allowed for sufficient time for the participants to ask questions, voice any concerns and consider their participation before the process officially began.

Parents, carers or guardians have not been asked to give written consent as the participants can make their own decisions and they are all above the age of 18. However, the parents, carer or guardian will be invited to sit in on the interview and observe if they wish. This option was incorporated as a precaution. However, knowing this is an option simultaneously eases the parents and the participants of any pre-existing concerns or worries. With the parents present there is also a lower risk of misunderstanding between the interviewer and the participant. As previously mentioned in section 3.1, people with learning difficulties can have trouble articulating their thoughts, and naturally the best person to interpret their speech and body language would be their parents, carer or guardian. If the parents, carer or guardian opted not to observe the interview there is the option of asking for their advice after the interview: this can be achieved by showing them the recording. However, the parents and the participants will be asked prior to the interview if this would be acceptable.

3.4 Respecting Confidentiality

To protect the participants' anonymity participant numbers will be used instead of their names in the report and interview records. As their names could potentially be used within the recordings, which jeopardises their anonymity, the recordings will not be included in the report content. As a further precaution only the participants' first names will be used within the interviews, and therefore, on the recordings. There will be no access to any raw notes or transcripts for anyone except myself. This precaution will prevent the interviewer's personal comments from breaching confidentiality or privacy. As mentioned is section 3.3, the participants will be signing consent forms; to attain absolute confidentiality, the participant signatures will be blurred out within the report/appendix.

As addresses and places are not relevant to the research or interview there will be no reason for these to be mentioned, therefore, the participants' location will be protected.

All records of the interviews and the participants' details (see documented details in section 6) will be kept on a personal laptop or on a personal One Drive account, both of which are password protected.

As the interviewer, a DBS [10] check has been obtained and previous work with all the participants has taken place, meaning they and their parents are fully aware that they are safe.

3.5 Assessing Harms and Benefits

The candidates will be required to answer a series of questions and then will use five pre-existing e-learners that will be provided and set up for them. When using the e-learners the participant will be asked to talk through what they are doing, why they are doing it and how they are feeling. These activities indicate no obvious potential harm.

The laptop and mouse used throughout the interview will be provided so no candidate will be at a disadvantage.

If the interview phase were to be removed there would be no financial harm or cost, however it would cause a severe impairment to the gathering of requirements. The interview allows the chance to observe first-hand what the desired audience most excels and struggles with when communicating and using an e-learner. Therefore, it will provide the majority of the design and functionality requirements.

The primary risk for this interview is if the participant withdraws, becomes distressed or seriously struggles to explicate their thoughts and feelings. However, through personal experience and the presence of a guardian or carer, even if that presence is not in the same room, this potential harm can be reduced. Breaks will be incorporated into the interview process in an attempt to prevent any distress, boredom or withdrawal.

3.6 Gaining Ethical Approval

Gaining ethical approval was a lengthy process. Due to poor communication from the university the project was delayed by a week or two as the aforementioned course "Research Ethics 1: Research Governance" or the relevant forms could not be located. This was due to website updates that resulted in outdated links for the required documents. After emailing the Ethical Officer, access to the documents and online course were eventually obtained and the ethical approval process commenced. As the project entails working with vulnerable adults it was essential to be extremely thorough when completing this course. The course allowed the user the ability to partake in a text/print version or an interactive version. The interactive version was chosen as it seemed more capable of ingraining the learning and maintaining engagement.

Completing this course is what encouraged the consideration of all the previously mentioned precautions. Therefore, it has proven to be extremely beneficial. After completing the course the required form was completed [Appendix 2]. The form was reviewed and after obtaining supervisory approval, the form was submitted.

Ethical approval was achieved a few days later:

Figure 2: Ethical Approval

Georgia Pocock; comsc-ethics; Matthew Morgan

Hello,

This email acts as formal ethics approval of your project.

Best,
George on behalf of COMSC Ethics
...

4 Requirement Elicitation

As the project revolves around people with learning difficulties, serious consideration surrounding the most appropriate and effective method of gathering requirements had to be undertaken. There are various methods for gathering requirements but deciding which method(s) were the most appropriate for the users and scenario was the real task.

4.1 Methods Investigated

The below sections will state the various methods of requirement elicitation that were considered and investigated. Each method will then be briefly explained; stating what it entails and justifying the reasons for using or eliminating it.

Questionnaires are one of the most popular methods. However, as the participants may have difficulty expressing their thoughts the use of open-ended questions would become impractical. Closed questions would not provide enough information and would not accommodate for confusion. Another issue questionnaires pose would be the assumption that the participants had the capability to read and write, or have someone available who could aid them in said tasks. From the aforementioned vision issues, and personal experience of volunteering in a book club, which aimed at improving people with learning difficulties' reading, it is apparent that this is not always the case. Consequently, questionnaires carried too many risks and it was decided to not include them in the requirement gathering process.

Another method, and a seemingly obvious choice from the beginning of this project, is *one-on-one interviews*. They allow the opportunity to ask a mixture of both open and closed questions, as well as the ability to prompt the participants for further explanation on a question if it is needed. This meant that if there was any miscommunication, there was the option to ask further questions, resulting in a clearer understanding. Another option would be to reiterate their answers back to them to ensure there was no misunderstanding. Forward thinking is another advantage to one-on-one interviews. It allowed for the questions to be thought of prior to the actual interview, ensuring that they are relevant, coherent and would aid in the gathering of the requirements. The one drawback to one-on-one interviews was the risk of the participants not being able to explicate, or potentially even identify, their struggles and successes.

As with one-on-one interviews, *group interviews* provide the opportunity to ask both closed and open-ended questions, whilst simultaneously allowing for the chance to gain further insight into the participant's answer should it be needed. However, conformity is a major risk when conducting a group interview. As the sample size was incredibly small it was imperative that the responses were unique and not influenced. Therefore, group interviews were disregarded as a potential requirement gathering method.

A *Joint Application Development (JAD)* session is usually completed in a group of five or more, and the participants "stay in session until a complete set of requirements is documented and agreed to" [11]. The issue with this method is, again, the fact that the session is conducted in a group manner, risking the participants' conforming to each other's opinions and invalidating the results. A further problem with this method is that the participants both have to stay in session and help define and document the requirements. Staying in session is impractical with these participants. As they have learning difficulties the chance of their ability to focus for long periods of time would be smaller [12], especially when the topic is around a subject with which they struggle to understand. As already stated, the participants cannot always explain what they want to say, so expecting them to assist in finalising the requirements would be unfeasible and unfair.

Prototyping is extremely useful and imperative to this project. Due to the participants having difficulty in communicating, and potentially not being able to vocalise or identify what they struggle with or find easy, prototyping provides a mitigation to this risk. Though another method would be needed to gather the preliminary requirements, this is a textbook method to ensure that the initial requirements were met and accurate. Prototyping accommodates an iterative process, which will ensure the product eventually meets the intended users' needs.

Use cases are another common form of requirement elicitation. However, as aforementioned in section 3.1, there are concerns about the participants' abilities to articulate their thoughts. Therefore, capturing their requirements in a use case could prove extremely difficult, as they may not know how they want said requirements to be achieved. Another issue with use cases would be the inability to identify and illustrate any issues found with the user interface or e-learner interaction [13].

Observations prove extremely useful when working with tacit and explicit knowledge. Observing the participants using pre-existing e-learners would make it easier to obtain knowledge that otherwise would have been inaccessible. Some usability and functionality design is so common that using those features becomes tacit knowledge; someone might have a difficult time explaining why they clicked a certain button or assumed they had to perform a certain action as it is habit and routine. Through observations a recognition for what routines the participants have internalised (e.g. red button with an x means close tab) can be obtained and then incorporated into the requirements and/or design. As the participants have difficulty explaining some of their thoughts, observations will act as a mitigation to that potential risk. Observations will allow for the detection of what the participants find easy and difficult, also helping them in identifying or elaborating on those issues by asking direct questions e.g. "How did you find using the keypad?"

The final method investigated was *brainstorming*. Initially, brainstorming did not appear beneficial to the requirement gathering process. The assumption was that through the one-on-one interviews, observations and prototyping the ability to produce ideas for the design would be easy. However, it became apparent that a list of requirements would be created, aspects the participants found easier and aspects that they struggled with would be identified, but an explicit solution to these problems would not be attained. Brainstorming was then incorporated as method of gathering requirements. The purpose being to produce

ideas and solutions to prevent the struggles recognised, and emphasise the positive functionality and design.

4.2 Method Used

It was determined that for this project a combination of requirement gathering methods was the best approach. The chosen methods were one-on-one interviews, observations, prototyping and brainstorming. Through this combination there is the ability to collate what the participants say with what is observed and ensure that valid and true results are being obtained. Prototyping acts as a safeguard to ensure that the design and implementation of the e-learner achieves the users' requirements and maintains the highest form of usability. Brainstorming permits the chance to explore a variety of solutions to the problems identified. Through the results achieved from the interviews and observations, an initial prototype can be created. This prototype can then be put through end-user testing, similar to the original observations, to create the iterative approach.

5 Initial User Interview Questions and Tactics

This section will explain the layout of the interview and the guidelines and tactics that have been used. These guidelines and tactics are precautionary measures to enable the interviewer to achieve maximum involvement from the participants and obtain the clearest results. As the users have DS it is especially important to ensure that these methods are acknowledged and adhered to when needed. These guidelines and tactics have been included in the subsequent section. They are vital to document as future development may result in someone having to conduct similar interviews.

A breakdown of the interview process is also provided with a demonstration of what questions will be asked and an explanation for each section. It is anticipated that due to the interviewees having special needs they may require prompts to encourage honest feedback. These prompts are also listed below.

To view how the interview findings are intended to be recorded please see section 6. A justification on why each section has been incorporated into the interview and the purpose behind it will also be provided in section 7.

5.1 Interview Guidelines

- Take breaks where necessary.
- Do not pressurise for an answer; wait for them to respond, if they take a long time ask if they would like the question rephrased.
- Find a place with few distractions to conduct the interview.
- Double check understanding e.g. You find maths challenging? Is that correct? You liked the use of coins in that game? Is that what you are saying/mean?
- If you struggle to understand a response, ask the carer or parent for help so there is no miscommunication. (Ask carer or parent if this will be acceptable prior to the interview).

5.2 Part 1: Icebreaker

- What have you done/are you going to do today?
- Are you enjoying Vale Plus/your job/class?
- Are you looking forward to our interview?
- What do you normally enjoy doing on a weekday/end?
  (General small talk. Observe environment; if in the house, are there any obvious hobbies surrounding you? Football, t-shirt design, books).

5.3 Part 2: General Thoughts on Mathematics

- Do you ever go to the shops to buy items for yourself/somebody else?
  - If no, would you like to?
  - (Food, magazines, sweets, drinks, clothes etc.)
- Do you ever get confused with how much money you should give to the shop assistant?
- Do you know how much change you should get back off the shop assistant or do you wait for the shop assistant to tell you?
- Do you ever use public transport?
  - (Bus, train, taxi).
- Do you ever use these without the help of a carer or parent?
- Do you ever have to pay for the transport?
  - (Is it paid for beforehand by parents, do you have a disabled person's pass?)
- Do you ever get help with maths and money and wish you could do it on your own?

5.4 Part 3: Observations

- Explain to participant what you expect them to do and what you will be doing.
  - (observing and taking notes about how they find the software).
- Ask them to talk while they are doing the tests to vocalise if they are confused, finding it easy/difficult etc.
- Set up the current system you are observing, let them familiarise themselves and maybe have a few goes.
  - (Observe familiarisation period). When they are ready start from beginning and observe the use of the system.
- Do another run through after they have completed the quiz/game:
  - How did you find that?
  - Why was it easy/difficult/confusing?
  - What would you change/keep the same?
  - Did you like the audio/use of keypad/use of pictures etc.?
  - Did you find it useful?
  - Would you use it again? Why?

5.4.1 Prompts

- If they are seriously struggling or say they cannot answer a question:
  - Why do you think you cannot answer the question? (Because there is no aid? Because you do not know how to work it out?)
  - What do you think would help you to answer this question?
    - (Calculator, tutorial, a visual aid [hand or counting blocks]).

5.4.2 Alternatives

- If the prompts are unsuccessful:
  - Ask if they would rather move on to another question (you answer for them based on observations) or if they would rather you help them answer it for themselves.
    - (This will help prevent demoralisation as they are selecting their preferred method of continuation. If they opt for you helping them, observe how they learn from you so that the method can be adopted into the end-product).

6 Initial User Interview Record

Below is the format of the initial user interview record. This template is how the recording of the participant feedback will be documented. After completing this form during the interview, the raw notes will be edited so that it fully adheres to the confidentiality rules (section 3.4). This template contains a brief paragraph within each section to explain the purpose of said section. For a more in depth justification please see section 7.1 – 7.4.

Primary User Interview Record
Interview Information
Name of interviewer: Date: Interview Location: Type of recording: (video/audio/written notes) Consent for recording: (yes/no)
General Information of Interviewee
The purpose of this section is to simply demonstrate that a variety of participants in terms of age, gender, experience and capabilities have been selected to allow for a wider demographic. Therefore, making the observations and analysis more applicable to a wider range of people with DS.
Interviewee number: Age: Living situation: Interviewee experience: (qualifications, education, jobs, volunteering etc.)

Part 1: Icebreaker Information
Typically, this section of the interview would be used to allow the interviewer and interviewee to gain familiarity with each other and start conversation flowing if they do not know each other. As acquaintances with the participants have already taken place due to ongoing volunteering, this section will act more like a conversation starter. It will allow for the question and answering to commence and familiarise the participant with the out of the ordinary setting.

Icebreaker answers:

Part 2: Mathematics Usage and Thoughts
This section enables a better understanding of what the interviewee feels towards mathematics and applying those numeracy skills to real-life scenarios. It will also get them in the mindset of understanding that this is a mathematical based interview and prepare them for the upcoming observations of them using current mathematical e-learners.
General Mathematics Thoughts answers:

Part 3: Observations
This section allows observations of the interviewee using the pre-existing mathematical e-learners. The decision was to opt for e-learners that are completely different to each other and tend to focus on different learning methods. This allows the interviewer to discern which learning method seems to best suit people with DS (to prove or disprove previous research). Simultaneously, it will enable the interviewer to pick out which aspects the participants struggle with, and which aspects they enjoy and understand. This could allow for the merge of a variety of learning methods and techniques to make for an adaptable and personal mathematical e-learner. One that incorporates all the good functionality across the pre-existing e-learners, whilst eradicating or improving upon the difficult usability factors.
Kid zone – Math Quiz http://www.kidzone.ws/math/quiz.html
Notable facts about this e-learner: (type of learning: reading and writing, kinaesthetic, audio, and visual. Adaptable? Colourful? More than one use? Use Mouse, keyboard or touchscreen? General overview) **Observations:** **Question Answers:**
BBC Schools – Teachers KS2 Maths Activities http://www.bbc.co.uk/schools/teachers/ks2_activities/maths/problem_solving.shtml
Notable facts about this e-learner: (type of learning: reading and writing, kinaesthetic, audio, and visual. Adaptable? Colourful? More than one use? Use Mouse, keyboard or touchscreen? General overview)

Observations: **Question Answers:**
Varsity Tutors – A-Plus Math Bingo https://www.varsitytutors.com/aplusmath/matho/addition
Notable facts about this e-learner: (type of learning: reading and writing, kinaesthetic, audio, and visual. Adaptable? Colourful? More than one use? Use Mouse, keyboard or touchscreen? General overview) **Observations:** **Question Answers:**
Coolmath4kids – Minus Mission https://www.coolmath4kids.com/math-games/minus-mission
Notable facts about this e-learner: (type of learning: reading and writing, kinaesthetic, audio, and visual. Adaptable? Colourful? More than one use? Use Mouse, keyboard or touchscreen? General overview) **Observations:** **Question Answers:**
BBC Bitesize – Igloo Shopping http://www.bbc.co.uk/bitesize/ks1/maths/money/play/
Notable facts about this e-learner: (type of learning: reading and writing, kinaesthetic, audio, and visual. Adaptable? Colourful? More than one use? Use Mouse, keyboard or touchscreen? General overview) **Observations:** **Question Answers:**

7 Initial User Interview Justifications

The above sections have shown the interview process and the way in which the findings will be recorded. Below is the reasoning for why each section has been incorporated, the section's purpose and what is hoped to be achieved by including it.

7.1 Interview guidelines

It was decided to incorporate interview guidelines into the interview plan to reduce the risk of miscommunication, distraction or deflation. As the participants have learning difficulties there is a greater possibility of confusion or discouragement if a question or activity is not understood, with a subsequently higher risk of a refusal of further participation. Therefore, patience and the offer to rephrase said question or activity has been recommended in order to mitigate this risk.

Selecting an interview area with few distractions should concurrently increase the concentration the participants will have during the interview. This will allow for coherent feedback and observations to be obtained, and prevent the interview from becoming disjointed and unclear from both the interviewee's and interviewer's perspective. Designated breaks will also aid in achieving higher levels of concentration, as they will prevent boredom and, therefore, further distraction or lack of focus. Organising the breaks prior to the interview will enable the breaks to be planned for logical times. (I.e. in-between e-learners rather than in the middle of an e-learner).

Miscommunication between the interviewer and interviewee could be a catalyst to conducting an extremely bad interview. Repeating the participants' responses back to them will allow the interviewer to validate their response, as well as aiding the participants in explicating their thoughts in a more concise manner (i.e. the interviewer can succinctly conclude the participants' responses and they can agree with the interviewer or correct them). If the interviewer struggles to understand a participant's response or actions, then a parent or carer's presence will ensure correct conclusions are made. Ensuring permission is gained from both the guardian and participant prior to the interview, agreeing to the parent/carer helping will ensure that everyone is aware of the procedure.

7.2 Part 1: Icebreaker

As there is a pre-existing relationship with the participants, the usual icebreaker questions, such as name, age, hobbies and academics/jobs have been excluded. Instead generic, conversational questions that are more applicable for familiarity have been selected.

As there is a relationship (in some form) with each participant an icebreaker session is essential. Although, the answers are not pertinent to this investigation, an icebreaker can encourage the interview atmosphere and design: the interviewer asking questions, whilst

the participants answer. This section will allow the interviewer the chance to do initial observations on how the participants react to basic, generic questions. This also enables the interviewer to absorb the participant's behaviour and reactions, ready for the core observations.

7.3 Part 2: General Thoughts on Mathematics

Including questions which ask whether the participants have experienced purchasing items on their own, or whether they have ever been confused by how much money to pay, is extremely important. Although, this section is not necessarily needed for the investigation and the results, it will help the participants feel invested and motivated for the interview, especially within the observations section. If they have never been given the opportunity to do this routine task, then it will encourage them to think about whether they would like that opportunity, and whether they think they would be successful in conducting a financial exchange. Alternatively, if they have experienced this then they know whether they can or cannot calculate the right amount of money needed to purchase their item. Either way it will create a connection between their lives and experiences and the tasks at hand, hopefully encouraging them to participate more and work harder. Predominantly, whether they have faced these struggles personally, or witnessed someone they know struggle with money, encouraging them to think of those times will provide good incentive for them to have a vested interest in the interview.

This section suggests a multitude of ways in which to ask questions surrounding the topic of money management e.g. shopping or transport. It also highlights independence. These two factors: money management and independence, are extremely important to most adults and hopefully this section will demonstrate that this is the same for adults with DS as well.

This section will also be used to highlight that the interview revolves around mathematics. The questions will provide a good introduction into the topic of the e-learners that the participants will be using in the observations section of the interview.

7.4 Part 3: Observations

A very diverse range of mathematical e-learners have been incorporated for the observations. From the research conducted it became obvious that methods of teaching surrounding interaction and visual aids are favourable for learners with DS [4]. As well as their enjoyment, there is a noted increase in the development of learning using this method.

In contrast to this information, one e-learner, 'Kid zone – Math Quiz', has been included that focuses on the reading and writing learning technique. This e-learner has been incorporated into the interview to either prove or disprove the above fact. Simultaneously, it increases the range of e-learners being used and also incorporates design features that the other e-learners do not possess. It is a lot more simplistic in its design and usability, and focuses more on improving the speed of simple mathematic equations. Therefore, it would be

useful to see how a participant responds to being timed. This e-learner would provide a useful starting point to the observations as it will allow for an eased introduction to the mathematics.

Figure 3: Kid Zone – E-Learner Layout Part 1

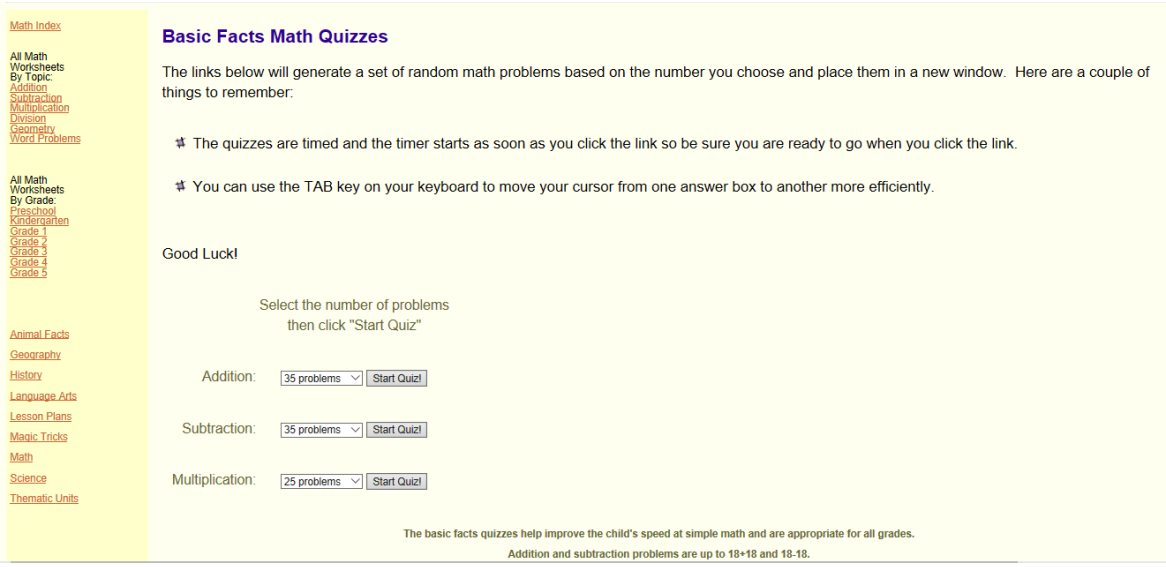
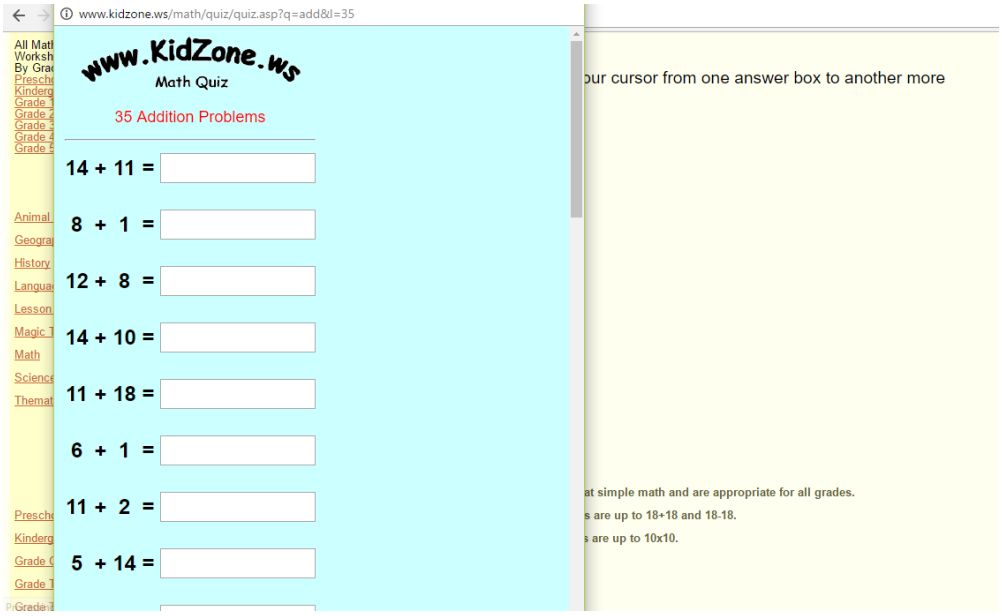


Figure 4: Kid Zone – E-Learner Layout Part 2



This is compared to the e-learner 'BBC Schools – Teachers KS2 Maths Activities'. This e-learner was selected to demonstrate the importance of not only being able to complete correct mathematical equations, but also achieving the best value for your money. It is an interactive shopping game which tests your ability to calculate the correct amount of money required to purchase your item, as well as encouraging you to work out how to spend the least amount of money. The feedback provided by the game once you have made a purchase shows very good communication, highlighting whether the user has given too much or too little money and stating whether you could have purchased the same item(s) for less money. There is a variety of text fonts used within this e-learner, so the importance of text font and size when designing for people with learning difficulties could be greatly demonstrated within this game. In conclusion, this game challenges whether there is a need to test the participants' value of money, as well as their ability to calculate the amount of money needed. It will also allow a comparison of how the participants respond to the feedback; whether they need to be told if they have paid too much or too little to correctly recalculate their answer.

Figure 5: BBC Schools – E-Learner Layout Part 1

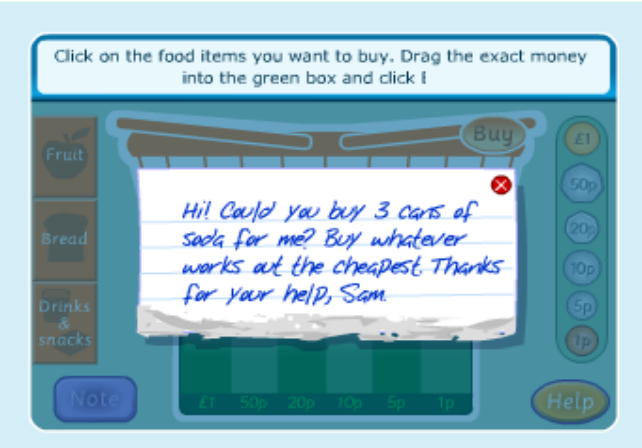
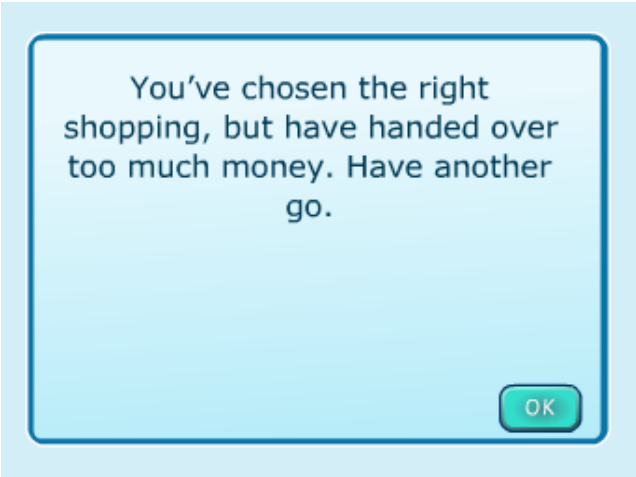


Figure 6: Kid Zone – E-Learner Layout Part 2

Figure 7: Kid Zone – E-Learner Layout Part 3



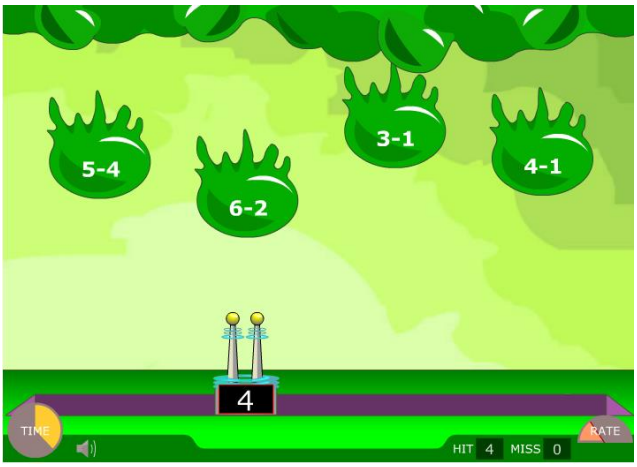
The e-learner 'Varsity Tutors – A-Plus Math Bingo' provides a mental maths approach to learning. It is still interactive in the sense that you receive instant feedback on whether your answer is correct or incorrect. However, whereas the previous e-learner encourages you to keep trying with the same question, this e-leaner provides the correct answer and then changes the question. From an initial perspective, this was not thought to be a useful feature in terms of the learning process, as users would not have the chance to recalculate and evaluate where they went wrong. However, as the participants struggle with mathematics, repeatedly expecting them to answer the same question until they get it correct could prove disheartening. Therefore, seeing how the participants react, in terms of continued attitude and motivation, to the outcome of incorrect answers on this e-learner compared to the others could prove very interesting. This e-learner provides a purely text-based instruction manual, explaining how to play the game. This text is extremely verbose and will provide some insight on how the purpose and instructions should be demonstrated within this project's e-learner. Another important design feature of this e-learner is that it is

easy to randomly click answers until you coincidently click on a correct answer. This will test whether the users realise this, and if they do, how they use it. It could evidence a faulty design that results in minimal learning.

Figure 8: Varsity Tutors – E-Learner Layout

'Coolmath4kids – Minus Mission' is an e-learner that requires the use of the keyboard. This e-learner has been included in the observations to discern whether the participants react well to the use of a keyboard instead of a mouse or touchscreen. There is a common assumption that the mouse is the most straightforward method of communicating to the computer. This e-learner will provide a fresh perspective that could demonstrate alternative methods of constructing the project's e-learner. It also has quite an extensive explanation on the intent of the game. However, it incorporates a visual aid and is about half the size of the previous e-learner's instructions. This could provide further insight on how concise the project's e-learner prototype instructions, questions and answers/explanations will need to be.

Figure 9: Minus Mission – E-Learner Layout



The 'BBC Bitesize – Igloo Shopping' e-learner is another shopping based e-learner that encourages the user to provide the right amount of money to purchase an item. Unlike the BBC Schools example, this e-learner has a level system that can be used by people of varying abilities. Witnessing how the participants react to choosing their own difficulty level, and whether they go back to change that level if they struggle or easily succeed, could suggest that a level feature is necessary. The main feature which this e-learner offers that the others do not is the use of audio assistance. With this e-learner the question can be read aloud. This is quite an imperative feature to have within at least one of the pre-existing e-learners, as it will truly demonstrate whether the audio assistance makes a difference to the understanding of the e-learner/question/explanation.

8 Initial Interview Synopsis

In this section the outcomes of the three participant interviews will be discussed. The main struggles and observations whilst interviewing the participants will be identified, as will any conclusions made surrounding the pre-existing e-learners. It will then be demonstrated how these findings will be incorporated into the project's e-learner prototype. As stated in section 3.3, it was ensured that all participants were made aware of the interview and recording process. It was explained to both the participants *and* their parents, to avoid miscommunication, and the participants each read and signed a consent form. [Refer to Appendix 3 for the consent forms and Appendix 4 for the initial interview records.]

8.1 Main Outcome

One clear favourite with two of the participants was the money based e-learners, whilst the third participant preferred a different e-learner but visibly understood the money based e-learners better. An interesting observation was that even though the participants were not capable of calculating, for example 20 + 10 + 4, they were capable of making 39p using coins. Their mathematical ability with money was vastly different to their abilities in general mathematics. It was concluded that this was most likely due to habit. This was later proven by the BBC Bitesize e-learner; the participants were not given a coin with more value than 10p. When participant 3 was asked to make 34p they could not initially work out how to make 30p without a 20p (i.e. they knew from habit that 20p and 10p made 30p).

The main purpose of the project was to create an e-learner that a young adult with DS could use with ease, and operate without assistance. This would simultaneously allow them the opportunity to work on their mathematical abilities, mainly in financial situations to improve their independence.

Having a money based e-learner will allow the users the opportunity to apply their mathematics in a situation that will show visible benefits to them. They will be more motivated to use the e-learner if they can see an improvement in themselves, which will be evident once they can go to the shops and make a money exchange with less assistance. As already demonstrated, the money based mathematics was solved differently compared to general mathematics. Therefore, it was concluded that it would be most suitable and better received to have a financial based e-learner (an e-learner based solely around a money exchange scenario) to help advance their arithmetic abilities in a financial situation.

8.2 Key Issues

In the subsequent paragraphs the main struggles met whilst conducting these interviews will be identified and explained. Through the research it was discovered that both of the below issues were possibilities and so they were not unexpected problems. However, it was interesting to see the issues arise in reality. They did prolong the interviews to an

unexpected variance of 1.5 - 3 hours (including breaks).

The main difficulty from the interviews was the participants' lesser ability to articulate their thoughts or reasons. Whilst observing their interaction with the e-learners it would be noticed that they were struggling with certain aspects; however, when questioned on what would help them overcome this issue the answer was often "I do not know". On simple issues like game and text size they could express that having the ability to make the text or game bigger would be extremely beneficial (and preferable). However, when the issues became more intricate (such as the phrasing of questions) they themselves could not comprehend why they did not understand what was being asked of them, and so they struggled to provide a solution. This was an issue that had been pre-empted and so it had been incorporated into the risk analysis. By conducting these interviews face-to-face, rather than via a questionnaire, the ability to observe all behaviour and trial solutions within the interviews was available and utilised (e.g. rephrasing a question they did not understand within the e-learner to see which phrasing they understood).

The participants over-estimating their abilities was the second issue encountered. From the research conducted at the beginning of this project, a separate project called POSEiDON was discovered. The main aim for this project was to create a system similar to Google Maps but aimed specifically at young adults with DS. They conducted an online survey which reached hundreds of people from across the UK, France and Norway. One of their findings was the 'major difference' in the feedback from the people with DS compared to the responses from the carers. This allowed POSEiDON to reach the conclusion that "people with Down's syndrome often claim to manage things on their own while carers are more reluctant concerning the range of their abilities. Carers may both over- and underestimate the independent skills of a person with Down's syndrome. But people with Down's syndrome are likely to overestimate their competencies" [4].

If the interviews had been designed and conducted without this knowledge an interviewer could have chosen to simply believe the responses they received, which would have greatly affected the conclusions. Two of the participants stated in section 2 of the interview that they struggled slightly with mathematics but were capable of going to the shops and buying a few items unaccompanied. The third participant did not go to the shops alone and said that they struggled with mathematics and needed some help. However, they specified that they could complete some calculations on their own. On the contrary to all of the participants' answers, their mathematical ability demonstrated in section 3 of the interview proved that they struggled with most calculations where the answer was above 10 (they ran out of fingers to aid in their calculations). This confirmed that the tendency to overestimate their competencies was true. This meant that when observing how they reacted to and handled certain usability and functionality aspects of each e-learner, vigilance had to be maintained as the participants may not vocalise or recognise their struggles. This fact was proven true in many cases throughout the observations. Prompts were needed and provided, and help with various activities such as: reading the text (due to size not illiteracy), figuring out what was required of them in the next stage and even helping them to return to the e-learner from the 'help' page. Therefore, to obtain valid and relevant requirements, the observations had to be maintained and the participants had to be encouraged to provide feedback, both good and bad.

8.3 Practices

Although the interviews attained various opinions, the conclusions were consistent. From these conclusions a set of good and bad practices have been developed that will aid in creating formal functional and non-functional requirements, available for reference in section 9.1.1 and 9.1.2. These requirements will then be used to derive an e-learner design for the prototype (available in section 9.2). The good practices will be adopted and emphasised within this design, whilst simultaneously negating the bad practices. This is while concurrently ensuring that all essential requirements and as many of the desirable requirements as possible are incorporated. From the end-user testing it can then be observed and questioned whether these good and bad practices are valid and whether the incorporation was successful.

The good and bad practices are listed below and justified in the subsequent section:

8.3.1 Good Practices

- Include a concise, illustrative and understandable 'How to Play'.
- Include the ability to have any text read aloud.
- Make the game adaptable.
- Incorporate helpful error messages.
- Include a 'Total' amount to pay.
- Keep the phrasing of questions and feedback clear and simple.
- Keep the logic of the game realistic.
- Keep relevant instructions always visible.
- Ensure good interaction throughout.

8.3.2 Bad Practices

- Having a time restriction or timer.
- Small text.
- Confusing syntax.
- Unusual or overly complicated words.
- Multiple aims.
- Unnecessary and confusing functionality.

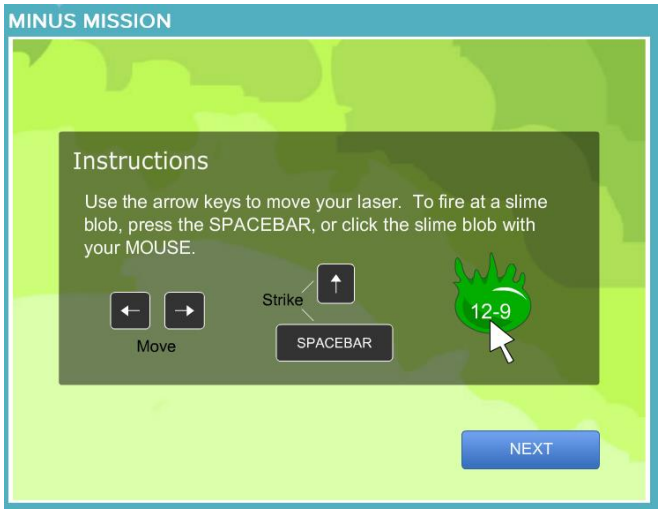
8.4 Validations for Good Practices

In the below sections an explanation will be provided explaining why these features have been highlighted as “Good Practices”. Examples of these features will only be given for the most obvious limitations and strengths of the pre-existing e-learners. This means that even if multiple e-learners have the same feature, not all of these e-learners will necessarily be evidenced.

8.4.1 Include a concise, illustrative and understandable ‘How to Play’

If there was an option to do so, each participant opted to be directed to the ‘How to Play’ before selecting “’Start Game’. With the two e-learners where this was not an option there was an obvious amount of initial confusion on what was expected of the participants. However, even though the participants seemed noticeably more at ease after reading the ‘How to Play’ it did not help them as much as it could have. All participants stated that the text for explaining the game was too long and they did not understand what it was telling them. In the e-learner ‘Minus Mission’ the ‘How to Play’ included a visual aid of what keyboard keys were required, this was an appreciated addition.

Figure 10: Minus Mission – Visual Aids In ‘How to Play’



All participants showed a vastly better understanding when visual aids were present. Even better, in the e-learner ‘BBC Schools’ there was a step-by-step ‘How to Play’ that took you through an illustrative guide on what each button did, with concise and comprehensible text to explain the visual aids. This was visibly the most effective ‘How to Play’.

Figure 11: BBC Schools – Step-By-Step, Illustrative 'How to Play'

8.4.2 Include the ability to have any text read aloud

Literacy is not guaranteed with any user, but it is less likely with a user with a learning difficulty. It was only in 1971 that the Education Act 'officially recognised that no child is "ineducable"' and so people with learning difficulties were given the right to an education [14]. This was only 46 years ago, meaning that anyone older than 46 could have potentially never received an education. The e-learner is aimed more at younger adults; however, this issue still applies. It has been recognised that people with DS can take longer to reach milestones such as reading, therefore requiring extra help [15]. Even though the right to an education was introduced 46 years ago, it has naturally been a working progress. Many teachers do not have enough experience working with people with special needs and many people can be ignorant to their specific needs due to this lack of experience. Consequently, there are still many people with learning difficulties who do not receive that extra support and, henceforth, struggle with reading (among other things). This fact alone makes the audio assistance feature imperative.

Alternatively, the lack of literacy could be due to medical issues rather than ability. There are many people with DS who face difficulties with their vision. In most cases, bad vision can be treated with glasses. However, there are conditions such as nystagmus that cause the eyes to move uncontrollably, 'usually from side to side' [16]. This can make reading an extremely difficult and time consuming process.

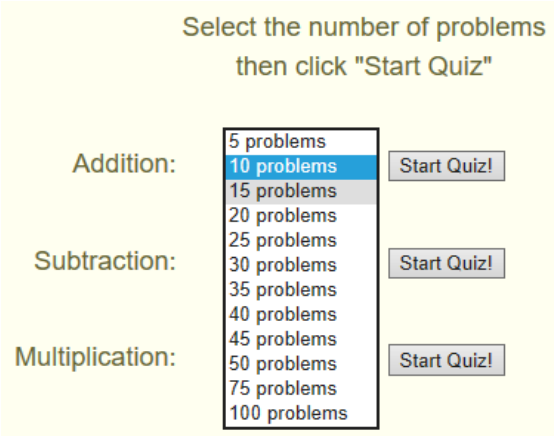
During the interviews all participants appreciated the option to have the text read to them. It allowed them to better absorb what was being asked of them and allowed for the whole course to run a bit faster. Even though all the participants could read, the process was slow and with certain words difficult, having the text read aloud removed some of that stress.

8.4.3 Make the game adaptable

With the few e-learners where the touchscreen was appropriate to be used, the participants found the functionality extremely useful. They seemed to operate the e-learner more accurately and appeared more confident in their actions. Using the mouse caused a similar level of confidence. The participants appeared to be least confident in using the keyboard, except in 'Minus Mission' which is very similar to a shooting arcade game.

All participants liked having the ability to choose the amount of questions they could answer with the e-learner 'Kid Zone'. This encouraged motivation and ensured that the participants did not get bored, having to answer more questions than they wanted to.

Figure 12: Kid Zone – Ability to Choose Amount of Questions Asked



Within the 'Varsity Tutors' e-learner the participants had the option to choose a difficulty level. All participants reacted to this option: as it was automatically set to medium all three participants opted to change this to easy. Similarly, with the 'BBC Bitesize' e-learner all three participants again opted for the easiest level of 'medium'.

Figure 13: Varsity Tutors – Difficulty Level

Figure 14: BBC Bitesize – Difficulty Level

Four of the e-learners were extremely small and this resulted in those e-learners having to be zoomed in on so that the participants could play the game. As the zoom functionality is a feature of the computer and not the e-learner, the e-learner having the ability to zoom or go fullscreen would prove extremely beneficial, as not all users can be assumed to be computer literate. As verified by the research, people with DS have notably poorer sight than most people [17]. Therefore, the need for the text and the game itself, to be at a reasonable size is imperative. All participants found the 'BBC Bitesize' game's fullscreen feature a huge benefit and relief.

Figure 15: BBC Bitesize – Ability to go Fullscreen

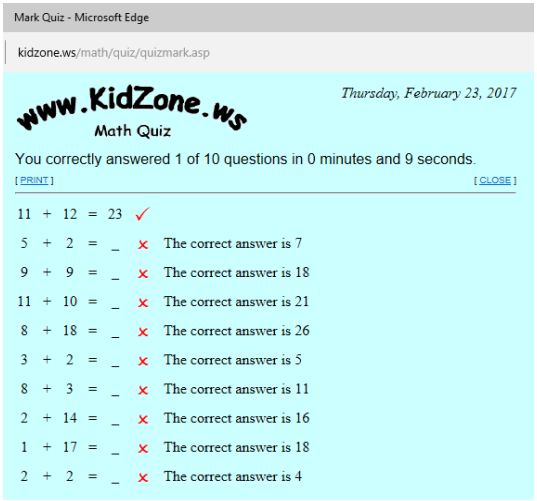
On the e-learners that did have the text read aloud, there was no option within the game to control the volume. This rested on the assumption that the user had a full understanding of how to work a computer and therefore adjust its volume. Two of the participants asked for help to turn down the volume as they could not do it themselves. They found the text reader in 'BBC Bitesize' and the background music in 'Minus Mission' too loud. In both instances there was the option to turn the sound off completely, but they did not want that.

However, there is evidence to say that most people with DS (40-80%) suffer with hearing issues [18]. The most common treatment with these hearing difficulties is the use of hearing aids and/or grommets [18]. This can alternatively, make their hearing more sensitive, if only initially. This is where the necessity for volume control, instead of the ability to simply turn the volume off or on, becomes imperative; the volume needs the potential to be adjusted to suit the user's needs. Although none of these features were essential to operate the game, they would be appreciated niceties that could be incorporated into the design.

8.4.4 Incorporate helpful error messages

On various occasions across all the pre-existing e-learners and with all the participants, an action would be completed incorrectly or unnecessarily. These actions often had either unhelpful or no feedback. The first participant, for example, when in the 'Kid Zone' e-learner pressed the Enter button, anticipating it would take them to the next answer box. However, it instead ended the game. There was no feedback to communicate what had happened and they got visibly disheartened by the amount of wrong answers they had (due to not answering them).

Figure 16: Kid Zone – No Error Message



8.4.5 Include a 'Total' amount to pay

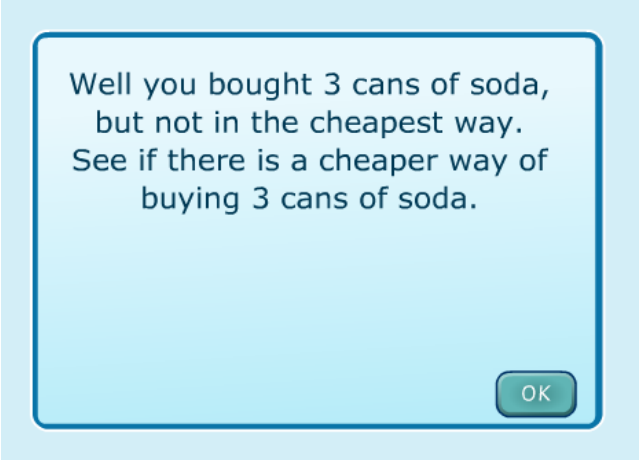
One issue that was observed with the money-based scenario e-learners was that there was no 'total' amount to pay displayed. This may seem like a counter-productive feature, as the purpose of the e-learner is to improve the users' mathematical ability, but as they are going to be practicing and improving their mathematics through achieving the total, a total is a feature that could prove extremely beneficial. When calculating the money needed to purchase an item all participants were becoming confused having to remember their total *and* what they had currently paid. Once a payment had been made they all automatically assumed that they had calculated their total wrong rather than giving the wrong amount of money. Therefore, showing the users what their total is would prove extremely valuable. This issue was more prominent in the 'BBC Schools' e-learner as they were purchasing multiple items. In the e-learner 'BBC Bitesize' only one item was being purchased and the price of that item was in the middle of the screen. Two of the users found this extremely beneficial with one saying, "I liked having the amount I had to pay in the middle".

Figure 17: BBC Bitesize – Total Present

8.4.6 Keep the phrasing of questions and feedback clear and simple

Within the 'BBC Schools' e-learner participants are expected to purchase items for the best value for money, as well as paying with the right amount of money. Two of the participants paid for their three cans; however, they had paid with the right money but had not purchased them in the cheapest way. This was the message that the participant received:

Figure 18: BBC Schools – Confusing Syntax



Although this syntax may make sense to some people, the participants understood this to mean they had not paid with the right amount of money. As a result, they tried re-calculating how much they needed to pay, instead of finding cheaper items.

In 'Minus Misson', the e-learner was attempting to ask what range of numbers you wanted in your equations. However, it was asked in an unclear way and all the participants ignored it. When the participants were encouraged to use it, they did not understand what it was asking them.

Figure 19: Minus Mission - Confusing Syntax

8.4.7 Keep the logic of the game realistic

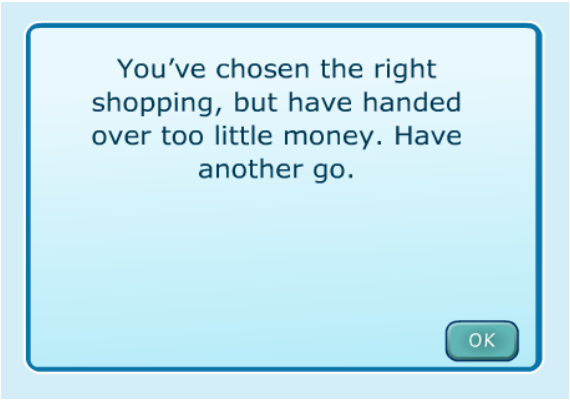
This only proved to be an issue with one of the participants. However, from experience it is apparent that when situations are not logical, or do not follow expected behaviour, people with learning difficulties can get confused, and sometimes frustrated. In this instance it was slight confusion with the 'BBC Bitesize' e-learner. Participant 2 could not understand why the item being purchased was on a plate and not in a basket. This illogical design was a big enough issue that the participant selected that e-learner as their least favourite. However, this was the task they performed the best in. This demonstrated how important the interface design can be over the usability and functionality of the e-learner.

Figure 20: BBC Bitesize – Illogical Design

8.4.8 Ensure good interaction throughout

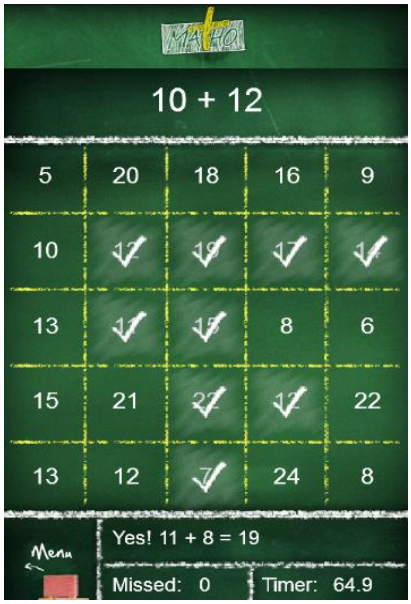
Having interaction within the e-learners proved extremely advantageous when dealing with an incorrect answer. When the e-learner communicated to the user (specifically in 'BBC Schools' and 'BBC Bitesize') that the answer was incorrect, it allowed the participants to recognise their mistakes and recalculate so they could achieve the correct answer. 'BBC Schools' had some of the best interaction in terms of feedback, as it not only stated that the participant's answers were incorrect but also that they had paid too much or too little. This constructive feedback ensured that the participants did not become unmotivated as they identified their mistake sooner.

Figure 21: BBC Schools – Constructive Feedback



Motivation proved to be at its highest when the participants were using the e-learner 'A-Plus Math Bingo'. This was because the questions which the participants had answered correctly stayed on the screen throughout the e-learner process, and subsequently motivation did not falter. When Participant 1 answered a few questions incorrectly in succession they said, "it does not matter, look at how many I have got right". This is most clear when compared to the other e-learners where the participants were visibly discouraged by an incorrect answer.

Figure 22: A-Plus Bingo - Constant Visibility of All Correct Answers



8.4.9 Keep relevant instructions always visible

An interesting observation with the 'BBC Schools' e-learner was that the participants did not fully grasp what they needed to buy. They would read the note:

Figure 23: BBC Schools – Instructions Note

But once the note was closed and they returned to the 'shop' none of the participants made the link that they had to follow the note's instructions. There was a disconnect between the note relating to the e-learner. Therefore, having the note or shopping list present at all times would prove extremely beneficial. It would also make the scenario more realistic, as, when you go to the shop with a list you tend to keep it with you at all times.

8.5 Validations for Bad Practices

In the below sections an explanation will be provided explaining why these features have been highlighted as “Bad Practices”. Examples of these features will only be given for the most obvious limitations and strengths of the pre-existing e-learners. This means that even if multiple e-learners have the same feature, not all of these e-learners will necessarily be evidenced.

8.5.1 Having a time restriction or timer

In ‘Minus Mission’ participants had to answer the question before one of the slime blobs reached the bottom of the page. All the participants stated that the time restriction ruined the fun of the game. Even Participant 1, who claimed ‘Minus Mission’ to be their favourite of the pre-existing e-learners, stated that they would be a lot more willing to play it on a regular basis if it was without the time restriction.

Figure 24: Minus Mission - Blob Time Restriction

Prior to the interviews not much thought had been put into the difference between a timer and a time restriction. However, they proved to be vastly different during the interviews. Whereas the timer was discreet and, although it “added a bit of pressure” this was not an issue that would prevent the participants from using the application again, the time restriction feature was. Even though the timer itself did not prove to be a repellent, it did seem unnecessary as it was not a feature that was truly understood or used by the participants.

8.5.2 Small text

Small text was a continuous issue with four out of five of the e-learners. The first four e-learners were not fullscreen size and so the participants struggled to read and navigate them. The creators had assumed that the user would be able to use the zoom functionality within the browser; however, as the participants were not at that level of technical ability they required help. The other assumption made by the e-learner creators was that their users would have good eyesight. However, people with DS are medically proven to have a higher chance of problems with their eyesight; "vision is poorer in children with Down's Syndrome than in typical children of the same age, and remains poorer even when the children have glasses for any long or short sight" [17]. There was an obvious positive reciprocation for the final e-learner, and all the participants opted for fullscreen immediately.

Figure 25: BBC Schools - No Ability to go Fullscreen

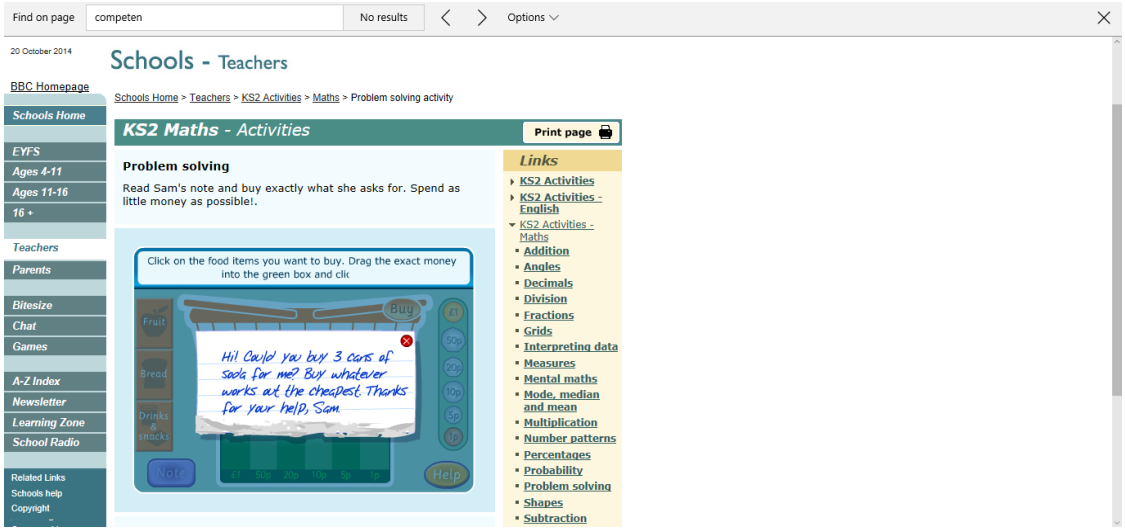


Figure 26: BBC Bitesize – Fullscreen

Another recognised issue with the text was the font. The participants did not struggle with any fonts except the one used in the 'BBC Schools' note. As the creators had tried to obtain a realistic written shopping list design they chose a hand writing style font. Although the idea helped to maintain the shopping theme, the font itself was not well selected and was difficult for two of the participants to read.

Figure 27: BBC Schools – Instructions Note Font

8.5.3 Unusual or overly complicated words

As well as avoiding confusing syntax (stated in good practices) there is also a need to avoid unusual or overly complicated words, a situation made more imperative when dealing with users who have learning difficulties. However, the extent to which this appeared in the interviews was surprising. It became noticeable that the participants were not completely comprehending the words addition, subtraction or multiplication. Initially, these appeared as everyday words but for two of the participants they became confused. This confusion did not subside until the questions were rephrased, replacing said words with "adding", "taking away" or "times (by)".

8.5.4 Multiple aims

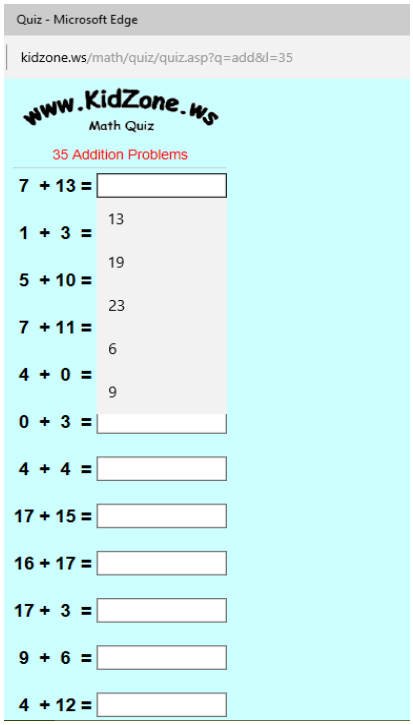
When the 'BBC Schools' e-learner was incorporated, it was mainly to observe how the participants handled having to figure out the best value for money, as well as the amount they had to pay. This proved to be an extremely useful obstacle to include as it demonstrated that including more than one aim was confusing for the participants. They often focused on just the one aim (the mathematics) whilst forgetting the other aim (the value for money). There was simultaneously the issue of one participant not understanding the goal of 'value for money' and they could not understand why spending less was beneficial. Although, this was an interesting revelation, it goes beyond the scope. However, it could be a topic worth considering for future development.

8.5.5 Unnecessary and confusing functionality

As aforementioned in section 8.5.1, there was the unnecessary use of the timer in several of the pre-existing e-learners. Although the timer would be used in a normal instance to observe if the user's ability and speed is improving, for these participants it was redundant.

One of the most strikingly confusing features was seen in the e-learner 'Kid Zone'. The e-learner remembered past inputted answers and displayed them to the user when they click in the answer box:

Figure 28: Kid Zone – Confusing Mouse Click Response



This was extremely confusing to the participants. As the interviews were being conducted on a new laptop, that had not used this e-learner before, the first participant did not experience this issue. However, Participants 2 and 3 both changed their answers once these past inputs appeared as they believed it was a multiple choice and they had to select the correct answer. This was not only an unnecessary and confusing feature, but also debilitated the game and led to incorrect answers being inputted, which ultimately led to the mathematics not being improved. This ultimately affected the participants' confidence in their own mathematical skills.

Another example of confusing functionality was demonstrated in the menu feature within the e-learner 'BBC Schools'. When opening the menu, participants had to click on the required tab. However, the pop out menu that appeared was hover controlled and disappeared when the mouse moved away from the menu. This was an issue that all the participants encountered. They would move the mouse as in all instances it was hovered

over an item, blocking their view. However, once they moved the mouse to obtain a clear view of the items, the menu would disappear. This caused obvious confusion initially, and once it happened multiple times, understandable frustration.

Figure 29: BBC Schools – Click/Hover Menu

9 Specification and Design

This section will detail what functional and non-functional requirements have been obtained through the good and bad practices. A brief description will be provided on what the requirement is, then the acceptance criteria will be stated. This will allow for the success of attaining a requirement to be measured more promptly and concisely, eliminating any ambiguity.

The prototype design will then be illustrated. To prevent any wrongdoing in the design, it will be evaluated against Neilson's Heuristics. This will allow for it to be tested against general standards as well as testing its applicability to the good and bad practices, and the functional and non-functional requirements. A Heuristic evaluation is usually conducted post-implementation. However, due to the time constraint this will be conducted on the design. This will provide the opportunity to objectively and unbiasedly evaluate the e-learner against universal ideals to ensure that it has adequate design and features before implementation begins. This will mitigate the risk of potentially wasting time creating inappropriate design, functionality or features.

As identified in the 'BBC School' e-learner, there was difficulty reading a font that had a handwriting style. Therefore, a font evaluation will be conducted to decipher which handwriting fonts are the most legible and favourable to the users. This is completed in the final subsection of this segment.

9.1 Requirements Analysis

As a vast range of good and bad practices have now been accumulated, it is important to categorise them into a formal set of requirements. To ensure that this mathematical e-learner is a success, obtaining these user requirements is crucial. Using the good and bad practices as a point of reference, a comprehensive list of functional and non-functional requirements will be developed. These requirements will then be categorised into essential requirements and desired requirements. As the aim of the project is to create an e-learner that is operable, understandable and liked by the users, these priority categorisations are spread out over both the functional and non-functional requirements.

Essential requirements are those that are deemed imperative for the e-learner to be deemed a success and accomplish the project's core goal; the "must haves". The desirable requirements are those that would prove beneficial to the project and the final iteration of the e-learner, but were not necessary for the project's success; the "should haves". Therefore, the desirable requirements will be dependent on the scope and time constraints of the project.

Below is an example of the functional and non-functional requirements layout. [A full list is provided in Appendix 5.]

9.1.1 Functional Requirements

Functional Requirements				
Requirement ID	**Requirement**	**Description**	**Acceptance Criteria**	**Priority**
01	Incorporate a randomised shopping list for users (acting as the question)	A shopping list should be present on the screen at all times with a random combination of the items available in the menu.	The shopping list should always be present. It should give a different combination of items after the previous list is successfully calculated.	Essential

9.1.2 Non-Functional Requirements

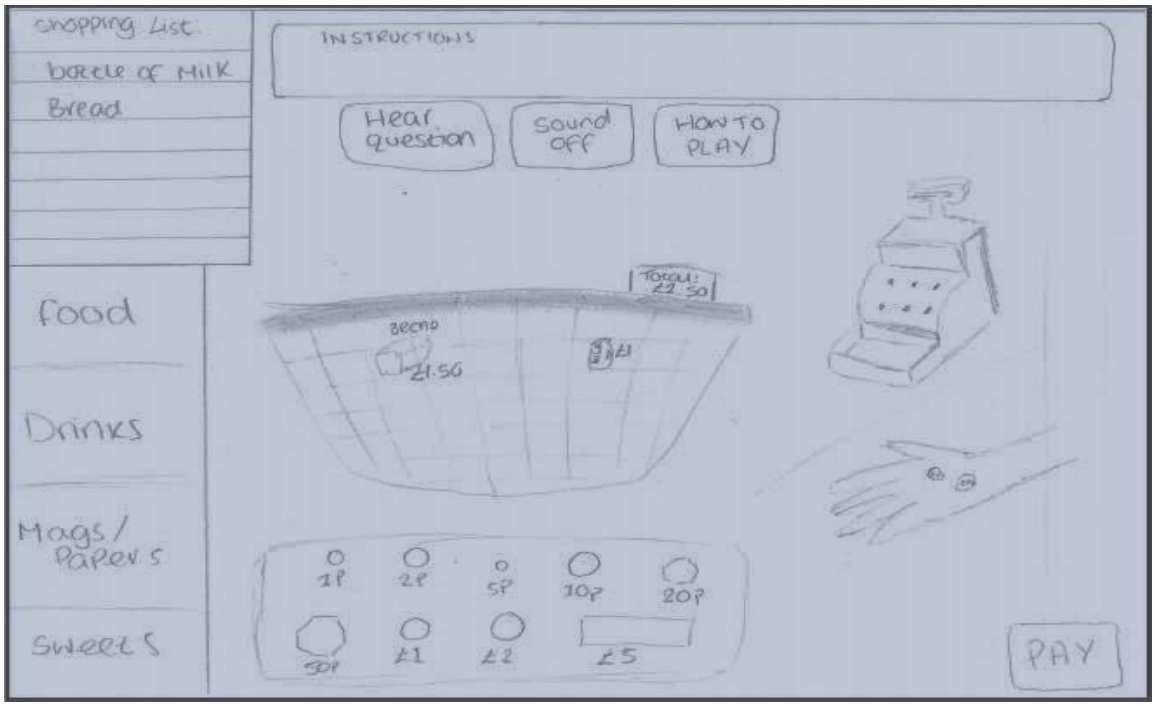
Non-Functional Requirements				
Requirement ID	**Requirement**	**Description**	**Acceptance Criteria**	**Priority**
13	Usability (ease of use)	The e-learner should be simple, habitual and intuitive to use.	Users can understand and operate the system with minimal assistance.	Essential

9.2 Prototype Design

Using the practices and requirements identified, a design for the initial prototype will be created. This design will incorporate all the good practices, negate all the recognised bad practices and ensure that, at a minimum, all essential requirements are met. Time allowing, the prototype will then be tested by the original three participants, as well as three new and unbiased participants, to establish if the e-learner has been a success. This iterative process will allow for the appropriate improvements to be recorded and potentially completed, should any be required.

Considering these practices and requirements, this design has been created:

Figure 30: Initial E-Learner Design



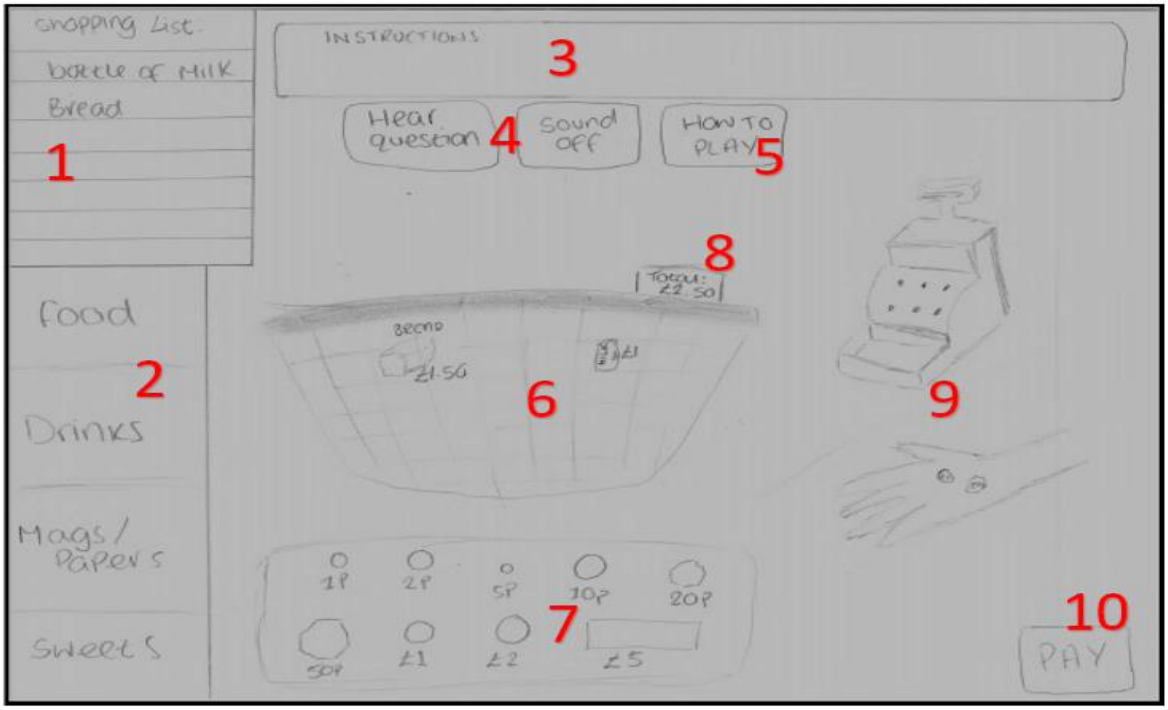
9.2.1 Heuristic Evaluation

To avoid making the same errors as the pre-existing e-learners a Heuristic evaluation was conducted. This would allow for an attentive assessment of the design to identify any interface or usability issues. If no issues were present, it simultaneously provided the opportunity to justify why each feature was included. There are multiple methods that could be used to conduct this evaluation. The most used set of Heuristics for usability evaluation are "Jakob Nielsen's 10 Usability Heuristics for User Interface Design" [19]. According to Nielsen's Heuristic evaluation a severity rating should be included in the evaluation to assess the impact of a Heuristic being violated and allow for resources to be assigned to fix the issue [20]. However, as this evaluation is surrounding the design and not the implementation, this has been discounted. Any Heuristic violation can be identified and corrected accordingly prior to implementation. As the design being evaluated was created based on good and bad practices that coincidently link very closely to Nielsen's Heuristics, it seemed the obvious choice to follow the Heuristic evaluation template created and provided by Rutgers University based on Jakob Nielsen's Heuristics [21].

Each design feature has been included for a purpose: to ascertain the good practices, functional requirements and adhere to Neilson's Heuristics. The image below is again, a drawing of the initial design. However, in this version each feature is numbered. Below the image is a Heuristic evaluation. The 10 Heuristics are listed and briefly explained. Underneath each Heuristic is an evaluation of how the design accomplishes said Heuristic, using the numbers to identify what design feature is being discussed. Therefore, the numbers will correlate to a justification for that design feature.

This method of evaluation is purely a pre-emptive approach to avoid spending time creating unnecessary functionality. Due to the scope it is imperative that all of the allocated time is utilised. This approach ensures that time is prioritised and allocated correctly and efficiently.

Figure 31: Initial E-Learner Design



Heuristics Evaluation of Mathematical e-Learner Initial Design

By Georgia Pocock **Date** 02/2017

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1. **Visibility of system status**

- Always keep users informed about what is going on.
- Provide appropriate feedback within reasonable time.

Evaluation

Through the inclusion of design feature 3, the summarised and essential instructions will be available at all times. This will ensure that the users are constantly informed and aware of the general actions expected of them. If a more thorough explanation is required on how to operate each individual aspect of the game then design feature 5 is available. By clicking on this button the user will be directed to a section demonstrating how to play the game. To ensure that the user is fully informed and understands the demonstration, illustrative examples will be provided. This ensures that the system not only adheres to Neilson's Heuristics but also to the identified good practices and functional requirements. As found in the research as well as in the interviews, people with DS greatly benefit from visual aids when learning or understanding [22].

The idea of design feature 9 is that when an item of money has been selected it will appear in either the hand or the till (depending on which design idea is incorporated) to illustrate to the user that the action has been registered. This will also allow for the user to be fully informed of their current payment.
Although you cannot see through the design, there will be relevant feedback throughout the game. When the user submits the money there will be a pop-up box informing the user on whether they have paid too little, too much or paid the correct amount. The phrasing of the feedback will be positive and motivational, whatever the message.

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2. Match between system and the real world

- Speak the users' language, with words, phrases and concepts familiar to the user, rather than system-oriented terms.
- Follow real-world conventions, making information appear in a natural and logical order.

Evaluation

This Heuristic links in strongly with the functional requirement and good practice of maintaining the e-learner's logic and ensuring that phraseology and wording is kept simple and understandable. As the users have learning difficulties this is an essential part of the design to ensure understanding and good communication.
The entire game is based around a shopping scenario. To ensure that the e-learner maintained "real-world conventions" design features 1, 6, 7 and 9 were included. All of these follow a real-life scenario. In a lot of shopping situations you go to the shop with a list (design feature 1) and once the items you are looking for have been found you add them to your shopping basket (design feature 6). Once your shopping is complete you pay for the items using real money (design feature 7) and give the money (in most cases) to a cashier (design feature 9). The design and functionalities have been laid out in a natural and logical order; the process going from left to right, top to bottom.
Throughout the e-learner any text will be expressed in everyday terms and words.

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3. User control and freedom

- Users often choose system functions by mistake.
- Provide a clearly marked "out" to leave an unwanted state without having to go through an extended dialogue.
- Support undo and redo.

Evaluation

There are only two potential design features that would result in incorrect actions. They are design features 4 and 5. If the user were to select to hear the instructions by accident they have the adjacent button to exit this design feature and mute the audio assistance. Design feature 5 would produce some form of pop-up or new tab to demonstrate the 'How to Play'. The plan is to incorporate an obvious method of exiting this design feature.

The only instance in which you would need to undo or redo an action would be when selecting the items you need to purchase or the coins you want to use to pay for the items. It is undecided how exactly this will be done but there will be the ability to select and deselect the coins/items, allowing for the action to be undone and redone as many times as the user likes.

---

4. Consistency and standards

- Users should not have to wonder whether different words, situations, or actions mean the same thing.
- Follow platform conventions.

Evaluation

This Heuristic is best demonstrated as being adhered to when reviewing design features 4, 5 and 10. These buttons all have different consequences, and therefore will have different presentations to visually represent this. Bootstrap will be used to aid in the formatting to achieve this Heuristic:

Figure 32: Bootstrap Button Designs

As you can see there are different coloured buttons for different categories. The blue “info” will be used for design features 4 and 5 and then the green “success” button for design feature 10.

5. **Error prevention**

- Even better than good error messages is a careful design which prevents a problem from occurring in the first place.

Evaluation

Through the use of design features 3 and 5 the design will be well explained and understood. However, an error could be met through the incorrect items being placed in the basket. Therefore, design feature 1 was created. This will allow the required items to constantly be present on the page, which reduces the risk of this error occurring.

The incorrect money being paid is an expected error as the e-learner revolves around testing and improving the user's financial abilities. Therefore, this is not perceived as an error nor does it require an error prevention. However, as stated within Heuristic 1, feedback messages will be included to communicate to the user if they have paid incorrectly and provide constructive hints.

6. **Recognition rather than recall**

- Make objects, actions, and options visible.
- User should not have to remember information from one part of the dialogue to another.
- Instructions for use of the system should be visible or easily retrievable whenever appropriate.

Evaluation

Through the logical design and informative instructions, the objects, actions and options are visible and obvious. From design feature 1 you can clearly observe what you need to purchase. Design feature 2 underneath is clearly labelled to contain the items being requested. Through the use of design feature 1, and due to it being on the page through the process, the user is not required to remember the items whilst searching for them. Similarly, design features 1 and 6 can be compared to ensure the correct items have been selected.

Design feature 8 is present to inform the user of the total price once the individual item prices have been collated. This allows the user to focus on calculating what money is required, rather than juggling the information of how much money they need versus how much they currently have versus how much they still need to pay.

Design feature 10 is simple and clearly states that the action completed (once this button is selected) is payment.

The users have been found to have poor auditory short-term term memory but strong visual memory [23]. Therefore, visually representing to the user what items they have selected, and how much their total is, is an important feature to adhere to as their recall is not a strong characteristic.

As already demonstrated in Heuristic 1, the essential and summarised instructions (design feature 3) are always visible on the screen. A more detailed and illustrated version: 'How to Play' is accessible through design feature 5.

7. **Flexibility and efficiency of use**

- Accelerators -- unseen by the novice user -- may often speed up the interaction for the expert user so that the system can cater to both inexperienced and experienced users.
- Allow users to tailor frequent actions.

Evaluation

Currently, there is no necessity to facilitate for this Heuristic. As the main purpose of this project is to create an environment in which the users can confidently operate and use an age-appropriate but easy to use e-learner, accelerators are not a main priority. Having said that, if this e-learner were to be developed in the future then this Heuristic could be introduced through the inclusion of difficulty levels. As mentioned in section 8.4.3, difficulty levels is a feature that all of the participants appreciated during the initial interviews. Therefore, it is definitely a method of both ensuring this Heuristic is met, whilst simultaneously making the e-learner available to all levels of ability; discussed in more detail in section 12.4.

8. **Aesthetic and minimalist design**

- Dialogues should not contain information which is irrelevant or rarely needed.
- Every extra unit of information in a dialogue competes with the relevant units of information and diminishes their relative visibility.

Evaluation

The only present dialogues on the screen are seen in design features 1 and 3. Both are relevant and needed. Design feature 1 allows the user to ensure that they have selected the correct items without having to constantly reopen a separate dialogue. Design feature 3 reminds the user of the e-learner process to ensure that minimum understanding of how to operate the game is accomplished.

The whole design is fairly minimalistic, but could appear busy initially. This is due to the amount of illustrations. However, as was found in section 2.1, the users learn and understand better through visual aids. Therefore, this is a necessity for this project's users.

9. **Help users recognise, diagnose, and recover from errors**

- Expressed in plain language (no codes).
- Precisely indicate the problem.
- Constructively suggest a solution.

Evaluation

Design feature 1 will hopefully prevent the error of incorrect items being placed in the basket. If the wrong items are selected as error message will be returned at some point reading something similar to: "The wrong items have been placed in the basket, double check the shopping list items." This is clear, concise and directly states the problem and suggests a method of fixing it. The basket will have a maximum of 3 items that can be placed

within it (as the shopping list will show a maximum of 3 items). This low number will also aid in the prevention of the error, or the recognition if one is made as due to the small number, a comparison between the shopping list and basket items can easily be made.
Another example of adhering to this Heuristic is when paying for the items. As stated in Heuristic 1 there will be a feedback message on payment which will either congratulate the user for calculating the correct amount of money or inform the user that they need to try again, explaining whether they have paid too much money or not enough. Again, this will be displayed and expressed in a clear and understandable way, and through the comment of "too much" or "too little", constructive feedback is provided.

---

10. Help and documentation

- Even though it is better if the system can be used without documentation, it may be necessary to provide help and documentation.
- Help information should be easy to search, focused on the user's task, list concrete steps to be carried out, and not be too large.

Evaluation

Through the use of design feature 5 additional help can be provided with a more detailed set of instructions. This design feature will allow the user to view an illustrative and text based 'How to Play'. It will be succinct yet descriptive and demonstrate to the user how to operate the game in steps to ensure it is understandable and clear.

9.2.2 Font Selection

To maintain the realism of the scenario the plan was to display the shopping list in a 'handwriting' style font. As identified with the BBC School pre-existing e-learner, there was some difficulty in reading a 'handwriting' style font. Therefore, a font exercise was conducted; the same phrase was written 20 times, each one in a different script-style font, then the participants were simply asked to select the font they most preferred (ensuring they could successfully read it):

Shopping List	Shopping List
Shopping List	**Shopping List**
Shopping List	Shopping List
Shopping List	Shopping List
Shopping List	Shopping List

Shopping List	Shopping List
Shopping List	Shopping List
Shopping List	Shopping List
Shopping List	Shopping List
Shopping List	Shopping List

The highlighted fonts illustrate the fonts that were selected by the participants. As they were so diverse, and no one font was selected multiple times, a second investigation was carried out. This time, the options consisted of the previously selected fonts only.

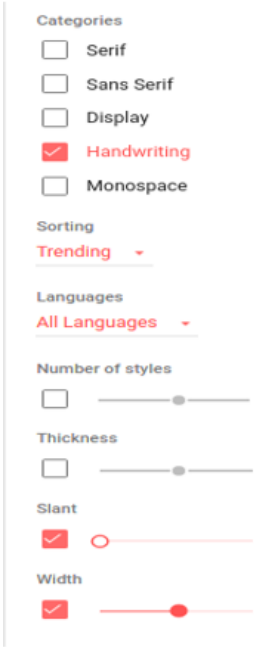
Shopping List	Shopping List
Shopping List	Shopping List
Shopping List	Shopping List

The reduction in the number of fonts to choose from allowed the participants to focus more on the fonts and their legibility, as initially they seemed overwhelmed and hurried in their decision. With fewer fonts, they each took more time to observe each font. Although there were still differing opinions the majority of the participants chose font “MV Boli” (as highlighted above).

As this exercise was not time consuming additional young adults with DS were involved alongside those who were in the initial interviews. Therefore, this decision was made based on the opinions of eight young adults with DS, aged 21 – 34.

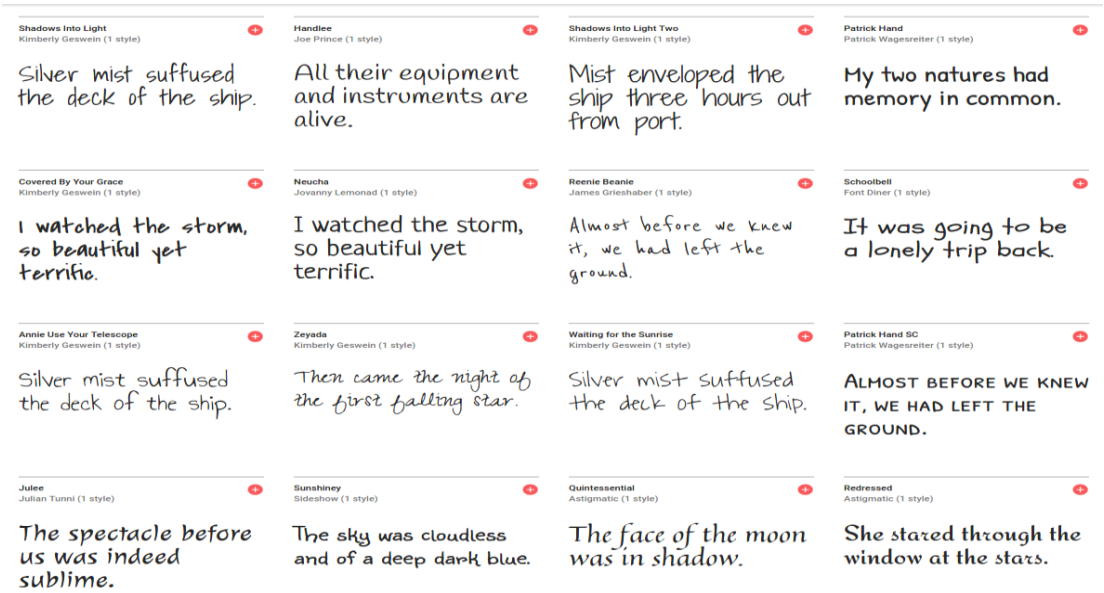
After conducting this exercise it became apparent that the chosen font was not attainable due to the lack of its availability in the JavaScript Bootstrap libraries. Therefore, the same exercise was carried out, this time using Google Fonts. Google Fonts contained a wide variety of fonts that were all open source. Google Fonts provided a filter for their font choices, which could be continually adjusted until it reached the specifications. Below, it can be seen that in this instance it was filtered to a ‘handwriting’ style font, the ‘slant’ set to 0 and the ‘width’ reasonably thick.

Figure 33: Font Filter



This was to aid in the font legibility. It was identified in section 8.5.2 that there were some issues with the participants being able to read the scrawled font in the 'BBC Schools' e-learner. This filter ensured that only appropriate fonts were included in the options. As was learnt from the last font test, too many options created confusion and made for unclear results. However, various options were needed for the font test to remain valid and impartial. Therefore, the filter was also used to unbiasedly remove the excessive options. These were the subsequent, appropriate possibilities:

Figure 34: Font Options



There were mixed opinions from the participants, but three fonts were highlighted as favourites.

Figure 35: Final Three Fonts

From here the favoured fonts were taken and, using the same participants, a final font test was conducted. From this test, the font chosen was Neucha, Jovanny Lemonad (1 style).

Figure 36: Chosen Font

Figure 37: Chosen Font Incorporated in E-Learner

10 Implementation

10.1 Tools and Framework

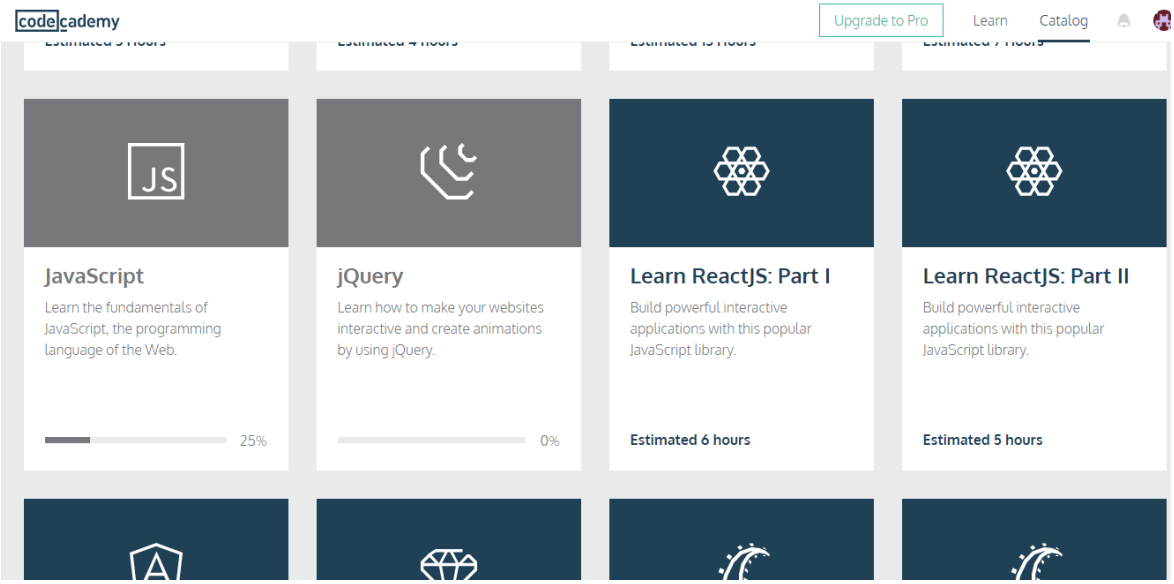
Selecting the correct tools and frameworks for this implementation was vital in safeguarding the success of the project. Due to a lack of experience in coding and implementation, choosing the wrong tool, technology or framework could have greatly hindered the project; mainly increasing the risk of not completing the project within the allocated time.

After a more thorough investigation into various coding languages it was decided to use HTML, CSS, JavaScript, JQuery and Bootstrap. As the requirements did not specify the need for storage of results there was no need for an active backend. A database, the evaluation of inputted data or cookies, or forms, which are all achievable using PHP, were not required. JavaScript enabled the capability to create a dynamic HTML page and content that interacts with the user. JavaScript also has less server interaction, which provided the ability to validate the users' input and would make the page faster and allow for immediate feedback. After doing this investigation it became apparent that JavaScript was the right language to adopt in order to fulfil the user requirements. Due to previous experience of using these three languages the implementation could be a lot more efficient than if the initial plan of PHP or a similar alternative were to be followed. Various libraries, predominantly Bootstrap, helped with the learning process and allowed the implementation stage to progress at a faster rate, which was essential given the time restriction. Through reusing blocks of code functionality, design and formatting could be integrated into the e-learner with minimal effort. Although these were extremely useful, they did require adaptation to apply them to the project's e-learner. It proved an extremely useful tool that aided in achieving the scope in the short time allocated.

Visual Studio Code was chosen to write and store the code. It is a free tool that maintained the simplicity of a code editor such as Sublime Text, but included the useful developer tools for code completion and debugging; as a novice coder, this was extremely valuable.

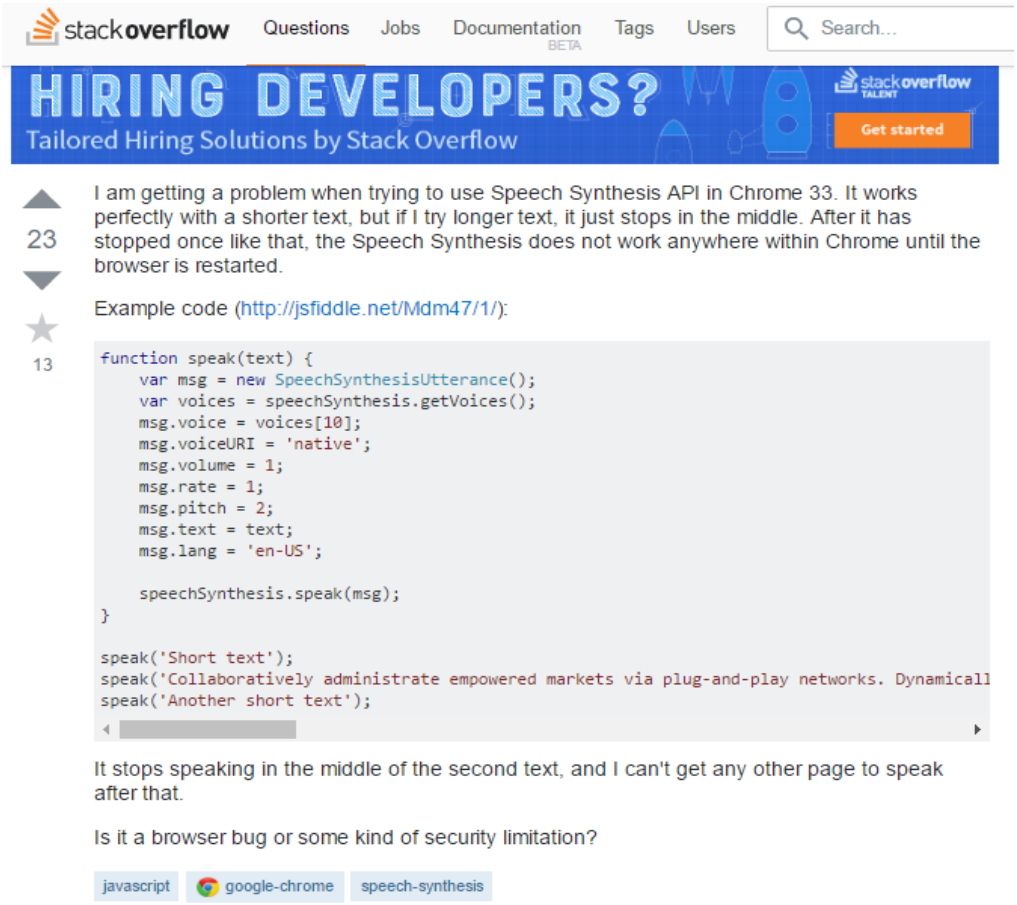
Even though access to all of these tools and frameworks was extremely valuable, they would not be useful with a lack of understanding or knowledge of what to search for initially. Therefore, Code Academy was used to self-teach what the code meant, how to write it and how to join the HTML, CSS and JavaScript together:

Figure 38: Code Academy Classes



Once there was full confidence in what had been learned, the coding began. There were occasions where limited knowledge was emphasised through an inability to remedy an issue or rectify functionality troubles. When this happened Stack Overflow: “a community of 6.9 million programmers, just like you, helping each other” [24] was used. It is a community of developers from novice to expert who ask and answer questions surrounding code. This was an extremely useful way to be enlightened on coding methods that were not obvious or not taught in Code Academy. It was also reassuring to be aware that other people were struggling with understanding the same coding language and issues, which provided great motivation to continue with the implementation.

Figure 39: Stack Overflow Question/Answer Example



10.2 E-learner Implementation

To view the entirety of the code, please view the attached zip file. In this section of the report the most vital, challenging and interesting parts of the implementation will be discussed. Implementation and decisions that may not have clear reasoning behind them will also be discussed.

Throughout the implementation of the e-learner it was ensured that all images used were reusable to avoid any copyright infringement. Therefore, whilst conducting the search for appropriate images, an 'advanced' search was conducted with the relevant filters applied. This resulted in the below filter combinations:

Figure 40: Labelled for Reuse with Modification

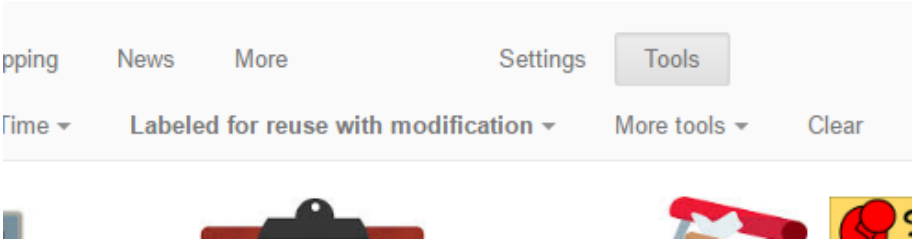


Figure 41: Free to Modify, Share and Use Commercially

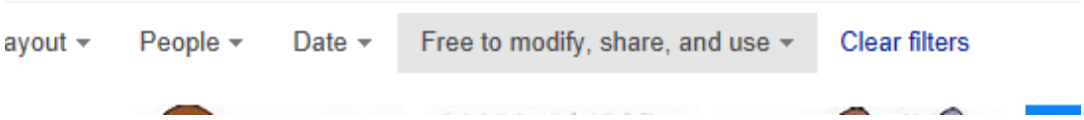
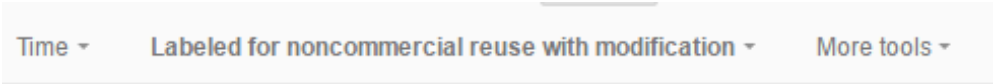


Figure 42: Labelled for Non-Commercial Reuse with Modification



If this e-learner were to be developed further outside of this project, then some images would have to be replaced with commercially usable variations. As many of the images used as possible were also labelled as “free to be modified”. This acted as a safeguard as although there was no plan to drastically change any of the images, adjustments to the shape, size and background were required on occasion.

Due to these filters some changes had to be made to the e-learner design. As can be seen in section 9.2 the initial design included a basket for the items to be placed in to. However, due to the limited options that were available after the advanced search filtering had been applied, this feature had to be changed to a trolley. This maintained the realism of the shopping experience and allowed the game to obtain a nice visual, whilst simultaneously abiding by the copyright laws.

Figure 43: Trolley Instead of Basket

As the users have trouble with their vision and as identified in the initial interview, small text can be difficult to read, a standard font size and line height was set across the entire e-learner. Placing these CSS rules in the 'body' ensured that all text displayed throughout the e-learner would maintain the minimum stated size and space between lines. This ensured that all text within the e-learner was legible. The text could then be altered later within the stylesheet if required and this would still apply due to the CSS override rule. Line-height was also implemented as a precautionary measure to guarantee the text legibility. By increasing the space between the lines, it simply improves the ability to read as the text is less restricted and squashed.

Figure 44: Font Size and Line Height

```
body {
  padding: 0;
  margin: 0;
  background: rgba(176, 196, 222, 0.25);
  font-size: 18px;
  line-height: 1.5em;
}
```

To make the 'How to Play' visually appealing the Bootstrap modal was used. This feature automatically acts as a carousal, playing like an automatic slideshow. As demonstrated in section 8.5.1 the participants did not appreciate being under a time restriction. Although in the initial interviews this was in terms of calculating the mathematics, it is most likely, if not more appropriate in this instance too. As the users have difficulty with reading, whether that be due to ability or vision, having the 'How to Play' (which will be a mixture of text and images) on a timer could prove distressing. 'How to Play' is such a vital part of any e-learner, as without it the game has the potential to be confusing and unusable. Therefore, no matter

who the users are this feature would not be placed on a timed slideshow, as this could result in essential information not being read in time. Hence, the data-interval attribute was used to rectify this issue.

Figure 45: Data-Interval

```
<div id="carousel-example-generic" class="carousel slide" data-ride="carousel" data-interval=false>
```

The most challenging feature to code was creating the ability to click on a single coin in the 'paid money' and have it remove itself. The code itself was fairly easy, especially after having just learnt how to clone the money to make it appear in the 'paid money' section. The real issue came when the remove functionality was tested. As the coins overlapped (to create a more 'natural' feel) the click would often remove the adjacent coin or sometimes multiple coins, instead of the one actually being clicked on. This issue was remedied by photoshopping the coin images to remove the entire background, even the transparent background, leaving the image to only be the circular coin. This meant that even when overlapping occurred, when a coin was clicked it was only that coin being clicked, not the transparent background of the adjacent coin. The 'stopImmediatePropagation' attribute was then added to prevent parent handlers from also executing when the child was selected for removal (stopping the coins from removing in multiples).

Figure 46: Code to Make Single Coin Remove on Click

```
$("#paidmoney").on("click", ".coin-in-hand", function (e) {
    this.remove();
    e.stopImmediatePropagation();
});
```

When the mouse was clicked in the 'paid money' area the coin being clicked on would be removed. However, if you continued to click in the 'paid money' area after all the coins had been removed, it would go on to remove the parent (original) coin. This was due to the fact that the code originally stated to simply remove '.money'. Therefore, on click, it removed all the money on screen.

Figure 47: '.money' class being referenced

```
$("#paidmoney").on("click", ".money", function (e) {
    this.remove();
    e.stopImmediatePropagation();
});
```

To overcome this the cloned coins needed to be assigned a separate class to the original coins. To achieve this the following code was added to the coin clone function:

Figure 48: Add Class to Cloned Coins

```
//clones coins so that they appear on hand, giving user visual representation of money being paid
$("#5pclone").click(function () {
    if ($("#paidmoney .5p").length < 6) {
        var $img = $("#moneycontainer .5p").clone(false).removeClass("money1").addClass("coin-in-hand").appendTo("#paidmoney");
        $img.css({ "padding": "-20px", "margin": "-20px", "margin-top": "15px", "height": "58px", "width": "66px" });
    }
});
```

Due to all the coins in the hand (the 'paid money') having their own class, that class could now be referenced instead of '.money' when writing the remove coin function:

Figure 49: Referring to Cloned Coins Class

```
$("#paidmoney").on("click", ".coin-in-hand", function (e) {
    this.remove();
    e.stopImmediatePropagation();
});
```

This then prevented the original coin from being removed, making the add and remove coin functionality completely successful.

When conducting a test on the add/remove coin function, it became clear that placing a maximum on the amount of coins that could be added to the hand had not been thought of. This meant that the user could add endless amounts of one or multiple coins to the hand. This was neither reasonable nor visually appealing. Thus, it was decided to restrict the amount of times a single coin to be added to the hand. This resulted in a limit of each coin being allowed to be added to the 'paid money' section a maximum of five times. There was no specific reason for choosing to restrict the coins at five, it just seemed like a natural number. Five 20ps make £1, five is a rounded number and by restricting each coin to five, the hand did not overflow should a user for some reason decide to add as many coins as possible to the hand.

Figure 50: Maximum Amount of Coins that Can be Added to Hand

There was also the challenge on how to add the item image to the basket without the images overlapping or becoming distorted. This was solved by creating three divs and positioning them accordingly on top of the trolley. An if/else statement was then used to add the items to the trolley.

Figure 51: Add Items to Basket

```
// adds the image of menu selected item to the basket.
$(".food .list-group-item").click(function () {
    const imageClass = this.classList[1];
    const image = $("<div></div>").addClass("basket-item").addClass(imageClass);
    if ($("#item1").children().length === 0) {
        $("#item1").append(image);
        image.css({ "height": "70px", "width": "70px" });
    } else if ($("#item2").children().length === 0) {
        $("#item2").append(image);
        image.css({ "height": "70px", "width": "70px" });
    } else if ($("#item3").children().length === 0) {
        $("#item3").append(image);
        image.css({ "height": "70px", "width": "70px" });
    }
    updateTotal();
});
```

Using the if/else statement meant that the items overlapping became an avoided issue. The statement also prevented more than three items being added to the basket, preventing overflow or someone steering too far from the shopping list. However, it did not entirely circumvent the anticipated issue of the images deforming. Each image is set to fill the div, and the div was set to the most diverse size. However, a method to make the divs dynamic so that the images could keep their shape and size was not discovered. Through trial and error it was found that having the height and width at 70px was the most visually appealing. Even though this compromise was reached, there is still a noticeable issue with some of the items when they are added to the trolley, the worst being the water bottle:

Figure 52: Distorted Water Bottle

When the requirements were first gathered it was highlighted that audio assistance was found extremely useful. There was some concern surrounding how the audio assistance would be accomplished in this e-learner. However, through a Web Speech API it was actually made quite simple. Although the code itself was easy to obtain and alter, it did come with several issues. With the Internet Explorer web browser the voice would read a full stop as “dot” instead of ignoring it; this was easily overcome by simply removing the full stops. As the audio assistance was reading bullet points, the full stops were not essential for the text to be understandable. The real issue came from Google Chrome. The audio assistance would not read the entire text, and after stopping mid-way through the text, the ‘Hear Instructions’ button would no longer work. After a great deal of research it was found that this was caused by a bug with Google itself and so the issue was fixed accordingly. For more information on this issue and the fix please see section 10.3. The code used to achieve the audio assistance is:

Figure 53: Audio Assistance Code

```
function hearInstructions() {
    const list = $("#instructions-list").children("li");
    let text = "";
    list.each(function (index, elem) {
        text += elem.textContent;
    });
    window.speechSynthesis.speak(new SpeechSynthesisUtterance(text));
}
```

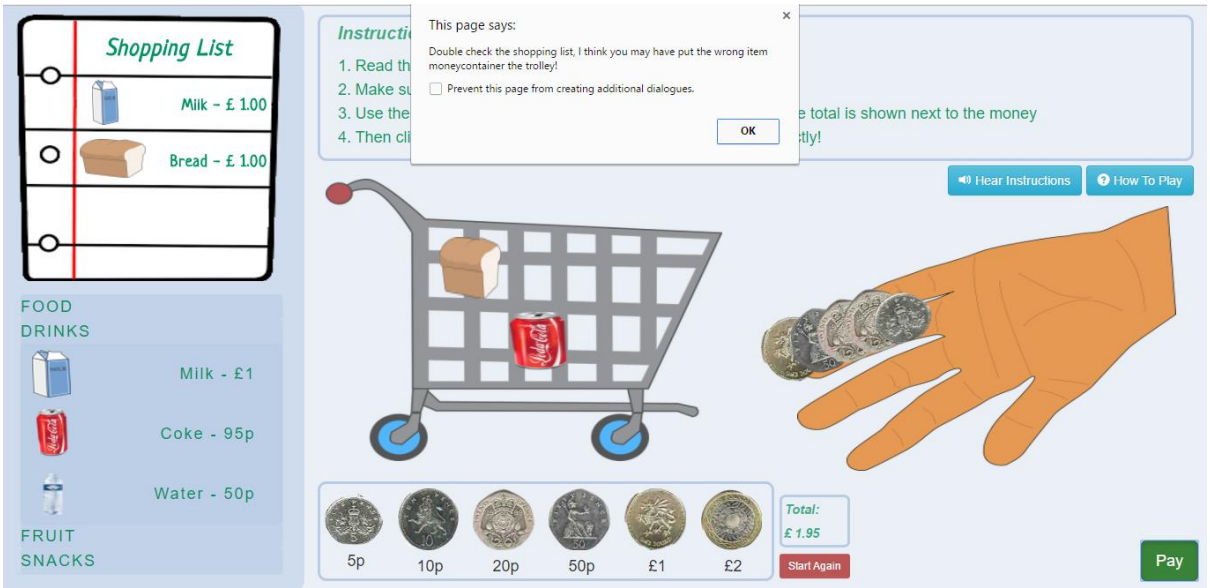
Although the audio assistance does work, there are still concerns surrounding its competence. There can sometimes be a few seconds delay between clicking the button and the audio assistance starting. This may cause the users to click the button multiple times, and as this was done during the testing stage, it is a valid concern. This would result in the audio assistance reading the text as many times as the button was clicked. Currently, a way to stop this time delay from happening has not been found, nor has a way to stop the audio

assistance from reading if the user wants to cut it off (e.g. they do not want to hear any more or they do click multiple times and want to silence the second round of talking). Therefore, the design feature of a 'Sound Off' button (labelled as design feature 4 in section 9.2) has not been successfully implemented.

The other concern with this audio assistance feature is the voice. As expected the voice is quite robotic, and at times can speak very fast. This could prove an issue for the users as they may need a longer amount of time to absorb the information. A solution to enable the voice to take a break in between bullet points was unfortunately not discovered, had there been more time, this would have been investigated more thoroughly until a resolution was made.

Code Academy provided a lesson about prompts and commands. Initially, these features were going to be used to return the error and "well done" messages to the user. After implementing them, however, it became evident how outdated they looked, especially compared to the rest of the e-learner which was intentionally made colourful and fun. The pop-up message was boring, ugly and had no z-depth; the background was still completely visible, making the message less obvious and confusing where the user's focus should be.

Figure 54: Outdated Pop-Up Message



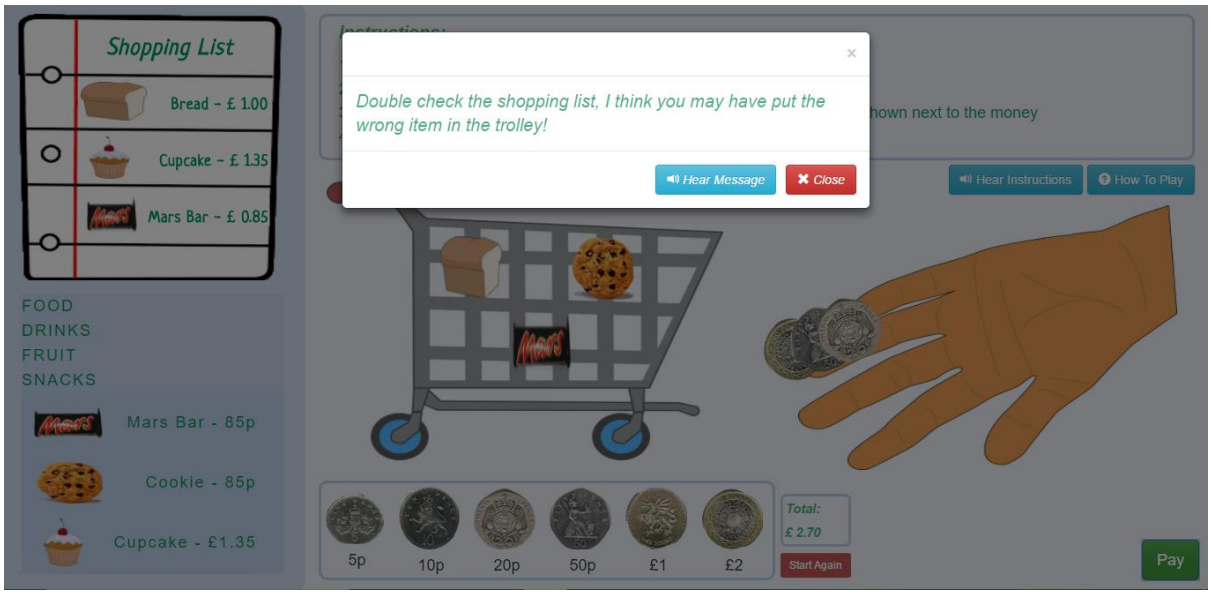
To overcome this design flaw, an investigation was undertaken and it was soon realised that a modal could be used instead. Using modals would create a nicer visual as well as creating a better flow and improving consistency, as a modal was used for the 'How to Play'. The code was changed accordingly:

Figure 55: Code Replacement for Pop-Up Messages

```
if (!compareLists(currentList, basketItems)) {
    $("#error-dialogue-Item #error-body").text("Double check the shopping list, I think you may have put the wrong item in the trolley!");
    $("#error-dialogue-Item").modal("show");
    //window.alert("Double check the shopping list, I think you may have put the wrong item moneycontainer the trolley!");
    return;
}
```

The modal version of the pop-up messages was preferable. It made a real difference to the user interface and it allowed the messages to blend a lot more with the style and appearance of the design. It also had z-depth, which is a vital feature. It causes a shadow over the e-learner making it less obvious, drawing the user's focus to the message.

Figure 56: Modal Pop-Up Messages



All of the modals included in the e-learner closed automatically when you clicked the backdrop. As well as making the 'close' and 'x' buttons slightly redundant, this functionality could have been confusing for the users. Having the ability to close the modal when you click outside of the modal itself can be an unclear feature. If a user clicks by accident, or on purpose, and loses the message, it can cause unnecessary confusion and distress, especially if this happens before they have read the vital information or if they did not mean to do it. Therefore, it was decided to make the backdrop static to prevent this from happening.

Figure 57: Stop Modal Closing on Backdrop Click

```
<!-- Modal showing "How to Play" -->
<div id="myModal" class="modal fade" role="dialog" data-backdrop="static">
    <div class="modal-dialog modal-lg">
```

Whilst coming to the end of the implementation the new £1 coin was released. After a discussion with the project supervisor, it was pointed out that the e-learner had not been updated to reflect this. However, as this £1 coin would only be one to two weeks old when the end-user interviews were conducted, an experiment was carried out. The point of the experiment was to decipher whether the new £1 coin should replace the image of the old £1 coin. At a volunteering event, the below image of the new £1 coin was shown to a number of young adults with DS:

Figure 58: New £1 Coin - Front and Back

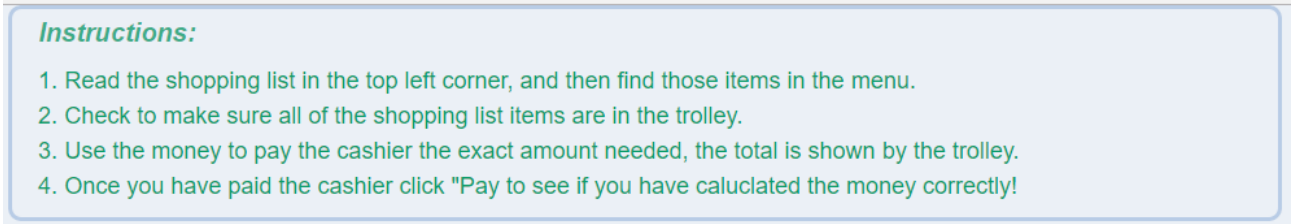
These participants, ranging from ages 17-36, were then asked to identify the coin. In total 18 people were asked and only seven could identify it correctly as the new £1 coin. Interestingly, due to its shape, numerous participants identified it as a “weird 50p” and due to its colour a lot of participants mistook it for the £2 coin. Therefore, it was decided to leave the old £1 coin: updating the coin has been included in the future improvements (section 12.3). Therefore, if this e-learner were to be developed further the new £1 coin could be incorporated when it is more familiar to the public.

10.3 Implementation Errors

Whilst going through the implementation and testing process, fortunately only two “showstopper” bugs were encountered [25]. Several minor issues were also met which were cause by generic coding errors such as missing a “#” symbol to identify an ID or using a full stop instead of a comma. However, these issues appeared less frequently as experience and knowledge progressed.

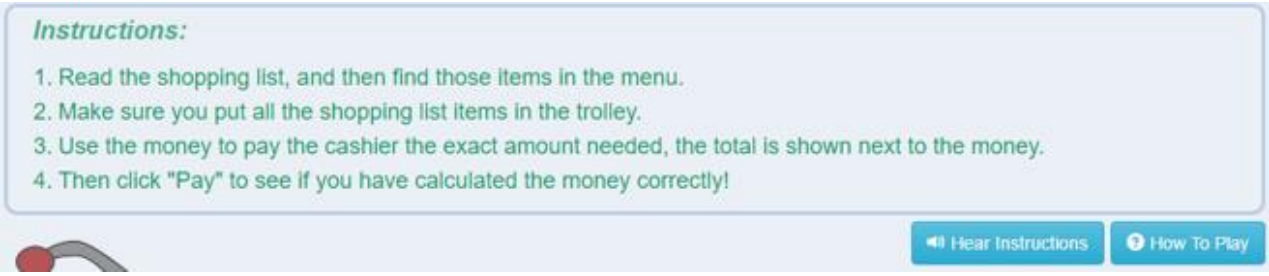
The first issue arose when the windows speech synthesis functionality was implemented; it was found during general testing throughout the implementation stage. This functionality was initially placed in the e-learner to assist in reading this text:

Figure 59: Audio Assistance Original Text



Upon click the text would be spoken as expected until it reached the word “cashier”. At this point the audio assistance would abruptly stop, as well as the ability to re-click the button. The code was edited to no avail. After further research it was found that there is a bug in Google. On using this functionality in Google the speech synthesis stops working and breaks the entire functionality if the text being spoken is longer than 15 seconds [26]. A test was carried out to time the audio assistance text and it did in fact stop at 15 seconds. To overcome this issue the text being spoken was simply adjusted to:

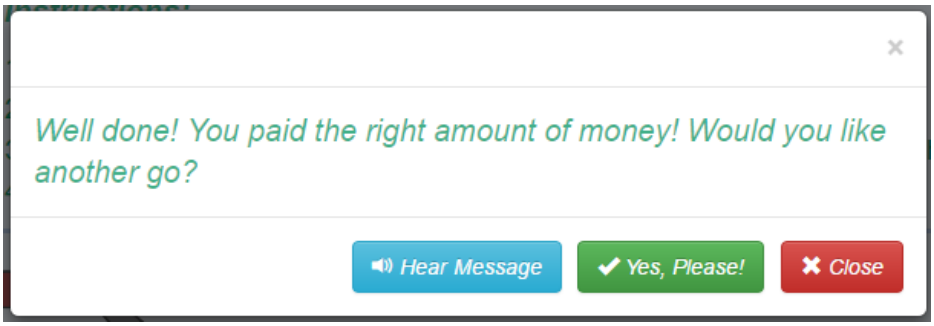
Figure 60: Audio Assistance Text Re-Do



Once this alteration had been made, the audio assistance was under 15 seconds and it worked perfectly. Now the button allows the entirety of the text to be spoken and can be clicked multiple times.

The second showstopper was less comprehendible, and although a workaround was found, an explanation or solution was not. After implementing the rigorous testing required for the test cases, it was discovered that with certain combinations of shopping list items, the wrong message would appear after clicking pay. More specifically, if the correct amount of money had been paid. Instead of returning this message:

Figure 61: Expected Message



It would instead return one of these two messages:

Figure 62: Returned Message 1

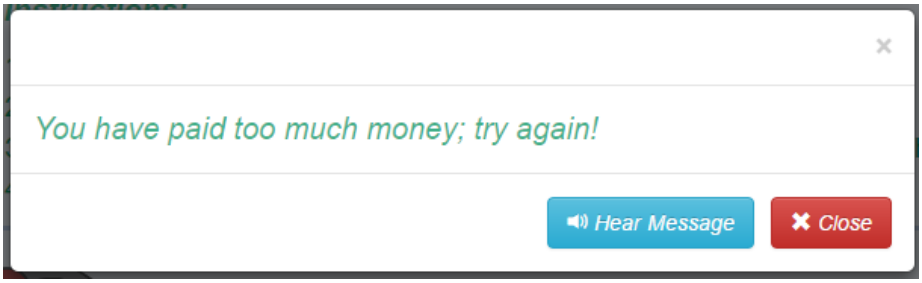
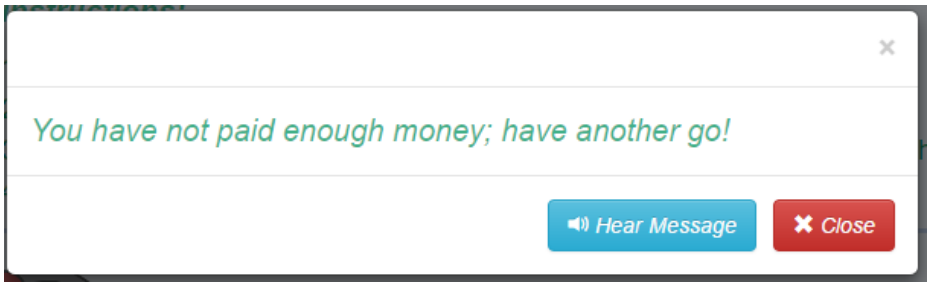


Figure 63: Returned Message 2



To resolve this issue the functionality of console.log was added to the JavaScript to show what was being returned in the background, hopefully allowing the root of the problem to be identified.

Many variations were tried in order to return different values:

Figure 64: console.log Example 1

```
function getMoney() {
    const items = $("#paidmoney").children();
    let money = 0;
    for (let item of items) {
        money += $(item).data("price");
    }
    console.log("getMoney = " + Number.parseFloat(money.toFixed(2)));
    // remove trailing decimal offset
    // eg 3.4000000000000004
    return Number.parseFloat(money.toFixed(2));
}
```

Figure 65: console.log Example 2

```
dex.html    style.css    main.js ×    bootstrap-theme.css
 *
 * @param {any[]} list1
 * @param {any[]} list2
 * @returns {boolean}
 */
function compareLists(list1, list2) {
    if (list1.length !== list2.length) {
        console.log("list length is false");
        return false;
    }
    for (let value of list1) {
        if (list2.indexOf(value) === -1) {
            console.log("list length is less than 1");
            return false;
        }
    }
    return true;
}
```

This console.log feature allowed for an investigation into whether it was the amount of money being paid or a difference between the basket items and shopping list items that was causing the error. However, they all proved to be working correctly.

Upon further reflection it was realised that this issue only occurred after the code to round the money to two decimal places was added. This feature was required as anything ending in zero e.g. 10p would return as '1' on screen. Therefore, the conclusion was reached that there was a possibility that it was rounding incorrectly. A comparison of the total amount of money in the basket and the total amount of money paid was added to the console.log feature to test this theory.

Figure 66: console.log Example - Basket Compared to Paid Money

```
function pay() {
    const money = getMoney();
    const basketItems = getBasketItems();
    let total = 0;
    for (let item of basketItems) {
        total += item.price;
        console.log(`Total basket: ${total}, Total given ${money}`);
    }
```

It was a long process as the e-learner had to be repeatedly refreshed until the error reoccurred. However, once the error was met again, the console was consulted and confirmed the theory.

Figure 67: Incorrect Error Message

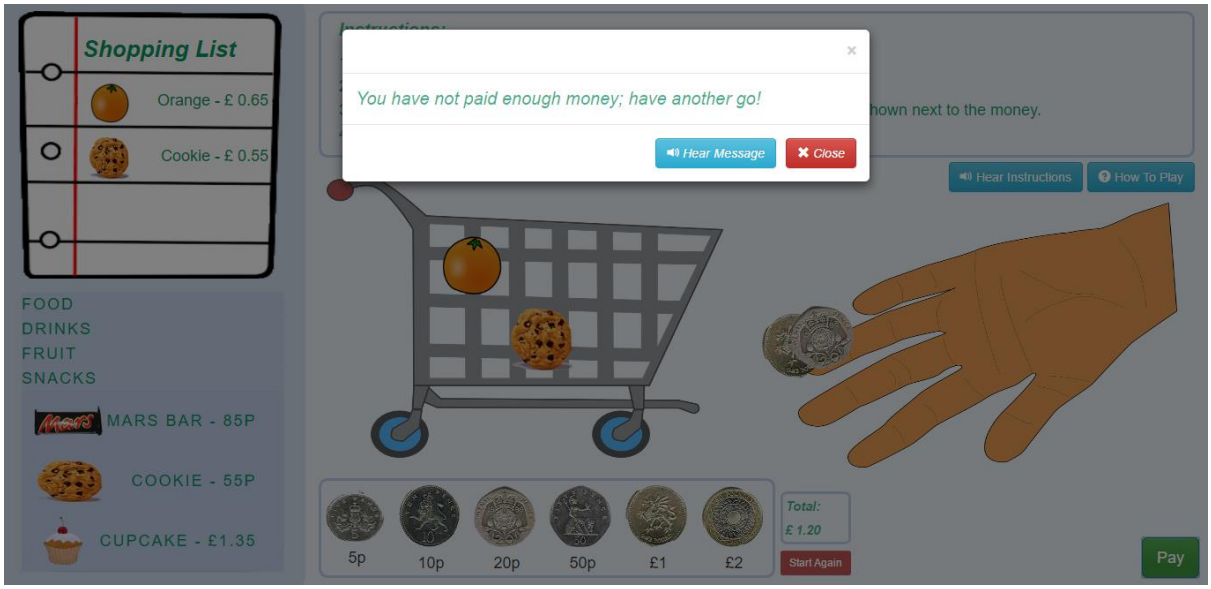
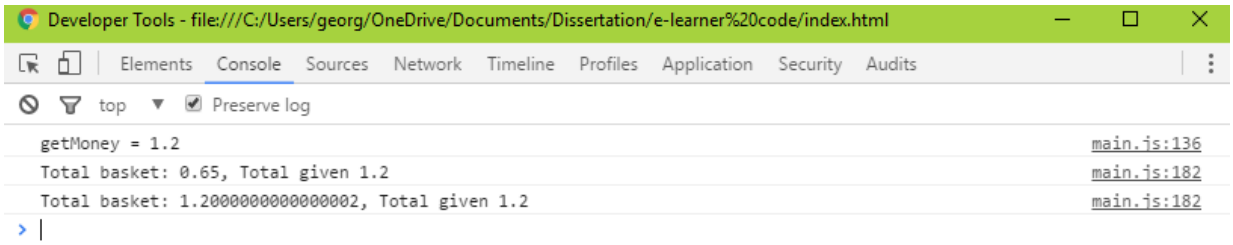
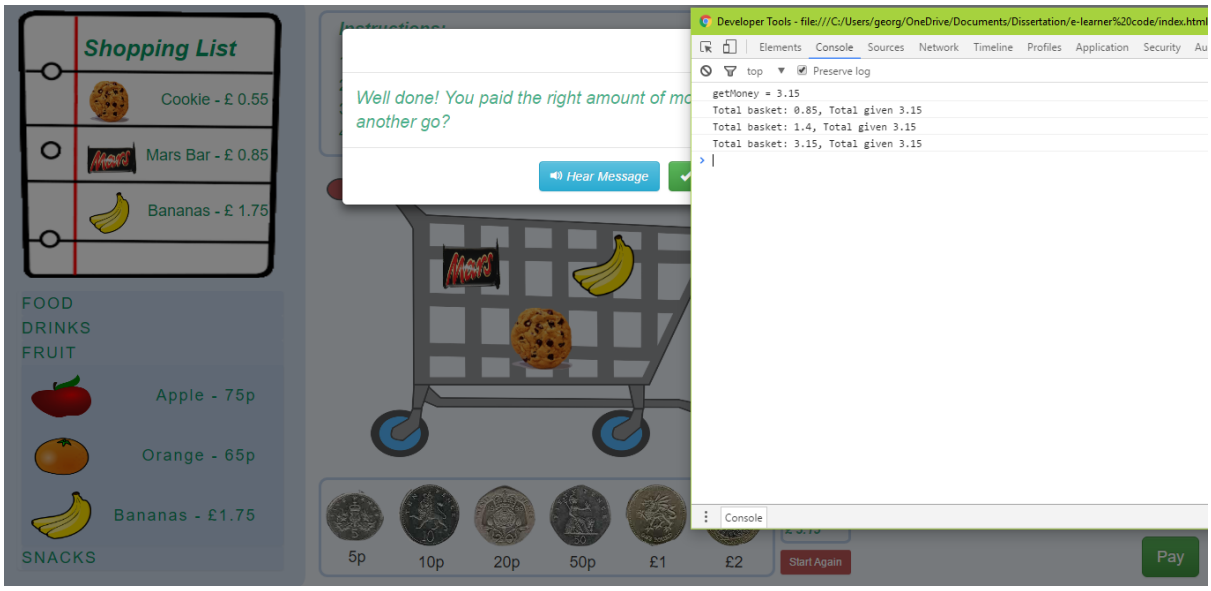


Figure 68: Console Data



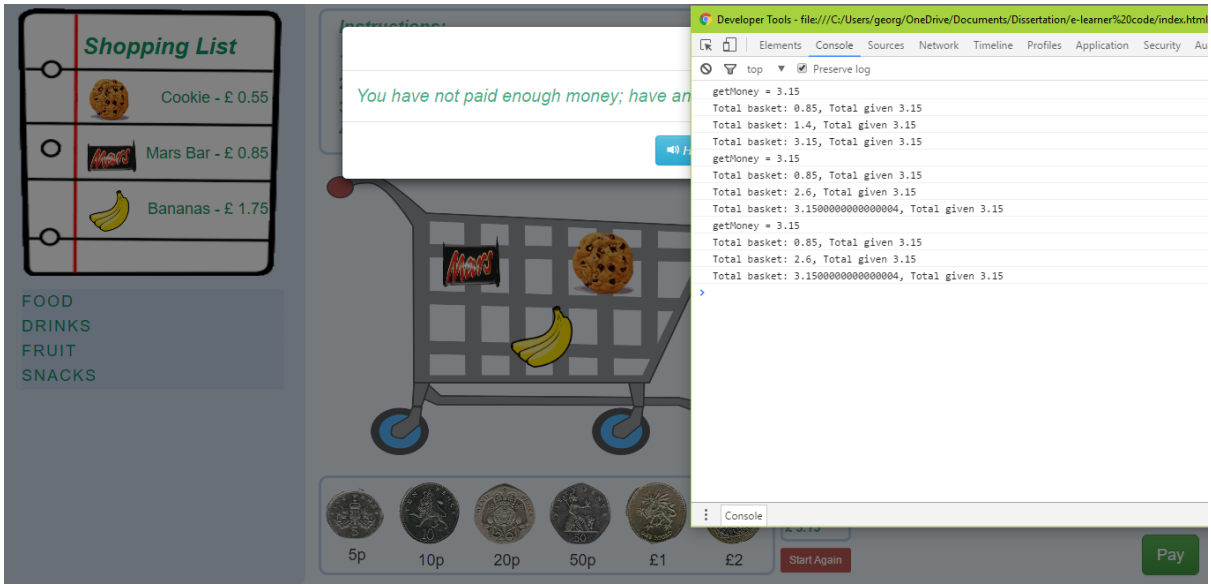
Upon further investigation into the issue it was realised that when the cookie was not placed in the trolley as the last item the error did not occur:

Figure 69: Error Not Occurring When Cookie is Not the Last Item



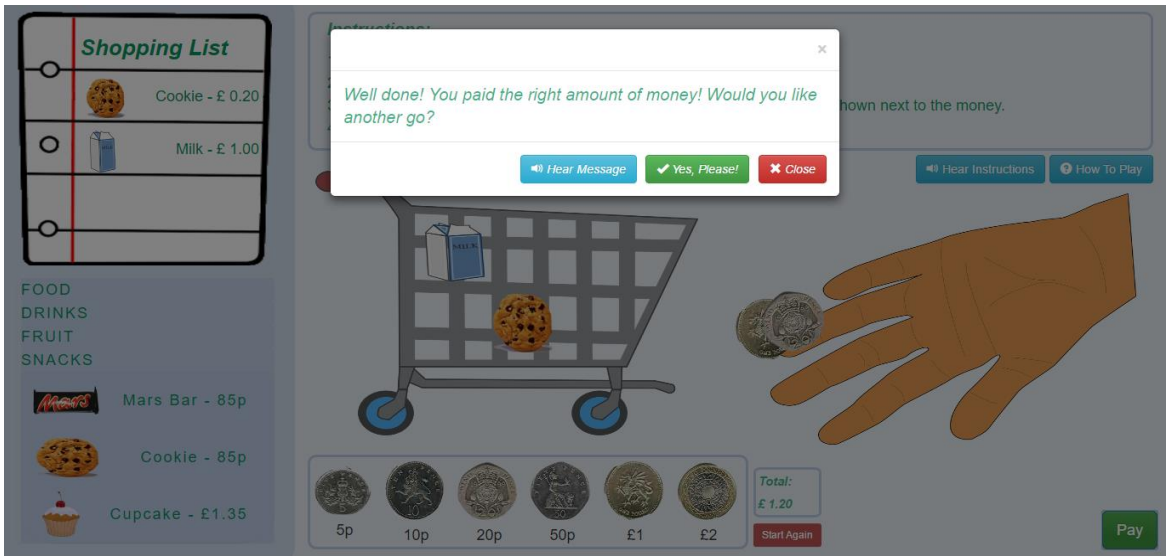
However, when the cookie was the last item in the trolley, the error would occur.

Figure 70: Error Occurring When Cookie is the Last Item



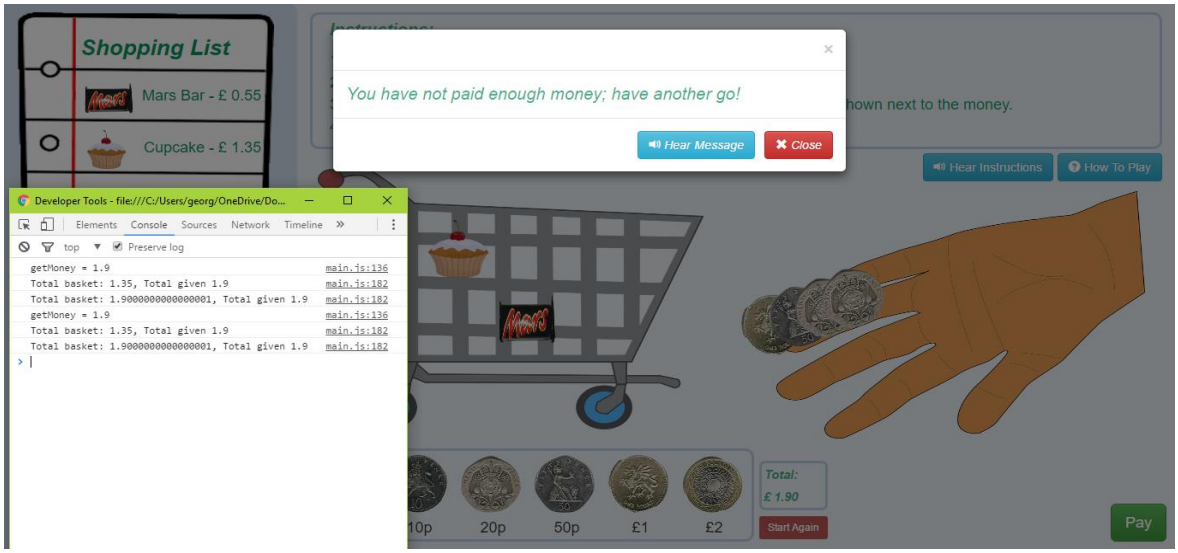
There was no obvious reason for why this error should happen. An investigation was conducted to see if the issue was with the price or the item, and so the cookie was reallocated another price: “20p”. When this was done the error did not appear again.

Figure 71: Cookie Working When Priced at 20p



For further investigation the price of the mars bars was changed to 55p. This was done to validate that it was the amount of money that was causing the error, not the item. This proved to be true:

Figure 72: Mars Bar Not Working When Priced at 55p



The only reasoning behind the potential cause was that the cookie was the only item that was priced at a value with a double number (i.e. two fives – £0.55p). However, there is no evidence to verify this. As it was an issue that was easily resolved, the price of the cookie was simply changed from 55p to 85p. Due to the restricted time scale, it did not appear to be time well-spent investigating the reasoning behind this error.

11 Results and Evaluation

11.1 Testing

Testing is an imperative part of any development process to ensure that the system runs as intended; meeting the requirements, whilst operating error-free. Although debugging of the e-learner will happen simultaneously to the coding process, not all bugs can be recognised and identified using this approach solely. Therefore, it is critical that a separate, more thorough method is also carried out to allow for the discovery of any potential issues that may go unnoticed during day-to-day use.

As the coding languages being used are HTML, CSS and JavaScript, the need for testing at the end of the development process is particularly important. The structure, layout and ordering of the code is a vital part of it running successfully. This means that adding new functionality increases the risk of pre-existing functionality breaking.

Once the e-learner prototype is complete, test cases will be carried out as a method of further and more vigorous testing. Using test cases provides the opportunity to individually assess each requirement, ensuring the correct steps are followed. The expected outcome is recorded within the test case providing an expectation to compare the actual results to, allowing for an unbiased validation on the pass or fail of said requirement. However, not all of the requirements can be tested this way as they are about the user's understanding and opinion. Therefore, the finished prototype will be presented to the users for end-user testing, this will accommodate an assessment of whether the requirements that are not within the test cases have been achieved. As some of the requirements are surrounding the user's opinions and behaviour, adopting the 'interview and observe' approach from the initial interviews seemed the most appropriate testing method for these remaining requirements.

The test cases will be carried out prior to the end-user testing, allowing for any previously unnoticed issues to be fixed beforehand. This will ensure that the e-learner can be confidently claimed as running error-free, preventing the end-user testing from being derailed. The test cases and the end-user testing will each decipher whether the e-learner accomplishes a mixture of both functional and non-functional requirements and more importantly, whether all essential and most of the desirable requirements are met.

11.2 Test Cases

This section contains an example test case using Requirement ID 01 and gives a brief overview of the overall outcome of the test case. [To view all the test cases please refer to Appendix 6.]

Requirement ID:		**01**			
Test ID:	**Description:**	**Test Steps:**	**Predicted Outcome:**	**Actual Outcome:**	**Pass/Fail:**
01	Randomised shopping list should be present.	Open e-learner.	Shopping list should be present on screen with a minimum of 1 to a maximum of 3 items.	Shopping list is present on screen with a minimum of 1 to a maximum of 3 items.	Pass
02	Shopping list should refresh automatically when user selects “yes” for another turn.	Find and select current shopping list items. Using the “Total” pay the cashier the money using the coins. Click the “Pay” button when you have paid the cashier all the money. If the money is correct a message should appear saying “Well done” and asking if you would like another go. Click “Yes, please!”.	When user clicks “Yes, please!” the page should automatically refresh and you should have a new shopping list.	When user clicks “Yes, please!” the page does automatically refresh and the user does have a new shopping list.	Pass
03	Shopping list should always be present and visible on screen.	Open e-learner. Go through each stage of game – start to finish.	Shopping list should remain present and visible in each stage (throughout game).	Shopping list does remain present and visible in each stage (throughout game).	Pass

The test cases proved to be extremely useful. Although not all test case requirements were successfully achieved, all the requirements that were labelled as essential were. Two test cases in total were failed: requirement 12 – cross-browser and requirement 19 – adaptability. The e-learner was completely compatible with Google Chrome, but other main browsers displayed compatibility errors. The game was fully functional in IE, but you could not see the majority of the images, making the interface confusing and diminishing the usability. Firefox maintained the same look as Google Chrome but had a slight sizing issue, resulting in a scroll bar appearing when the menu was expanded to purchase the items.

Figure 73: E-Learner in Google Chrome

Figure 74: E-Learner in Internet Explorer

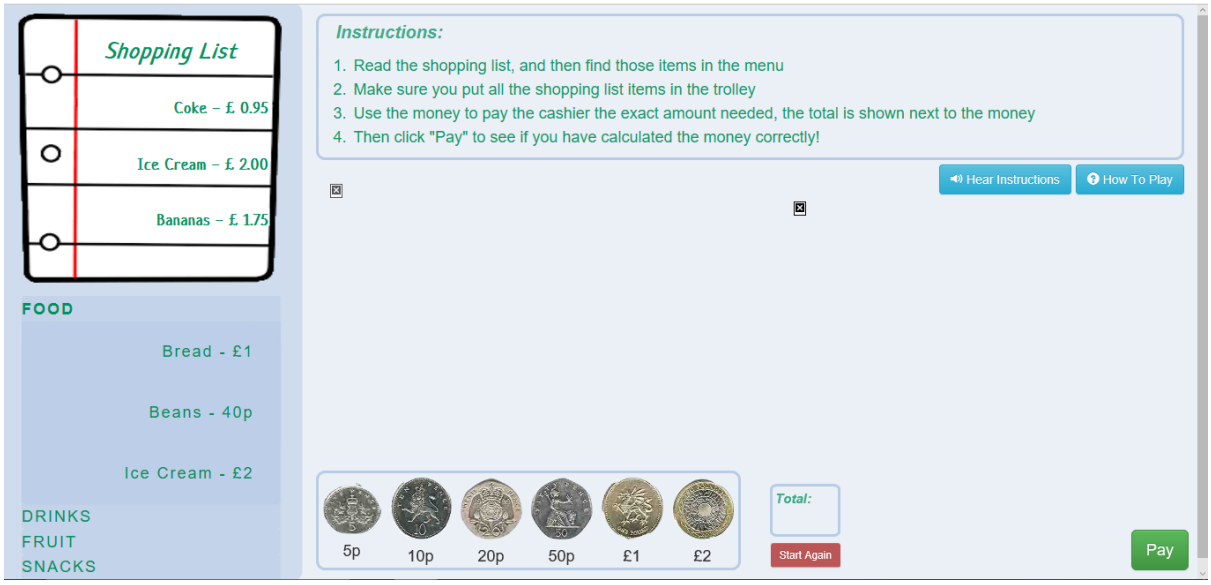


Figure 75: E-Learner in Mozilla Firefox

The adaptability was achieved in terms of incorporating audio assistance and the option to use a mouse or touchscreen to operate the e-learner. However, the further adaptability criteria of volume control and choosing the amount of questions to be asked was not included.

11.3 End-User Testing

These interviews will be conducted with the three original participants. This will allow for a valid comparison from the users. As they have used the pre-existing e-learners, a thorough assessment as to whether this e-learner is an improvement on the pre-existing e-learners used in the initial interview can be obtained. In addition, three new participants will be interviewed. The reasoning for this is that the e-learner is meant to have ease of use; be intuitive, stress free and operable. As the previous three participants have direct experience with the five pre-existing e-learners, these three new participants will be unbiased users. They can accurately judge whether the e-learner achieves the requirements from an untainted perspective. As the original participants had to sit through a long interview, using five e-learners, they may obtain the impression that this e-learner meets the requirements or is better, simply due to the past interview experience. The three new participants do not have that experience and so can judge whether the e-learner accomplished the requirements generally.

11.4 End-User Interview Questions and Tactics

The same structure, process and guidelines will be followed as with the initial interview. The icebreaker section is being used again to integrate the interview atmosphere into the situation. This will hopefully get the participants comfortable with being asked questions, and answering them in return. The interview will then progress straight into the observations. In the initial interviews the participants were observed using five pre-existing e-learners and so their chance of boredom was increased. As the only e-learner under observation within this interview is the project's e-learner, there is less chance of the participants becoming bored or frustrated. Therefore, the section on "General Thoughts on Mathematics" is not required as a motivation enhancer.

In addition, there will be a list of questions to be asked at the end of the observation process. As stated numerous times the participants can have difficulty in explicating their thoughts. These questions have been included to eradicate this risk, allowing for a question to be asked requesting their input on each requirement not tested within the test cases. This will help in getting a valid and clear answer on whether each requirement has been successfully achieved. To prevent any risk of the questions directing the participants' answers, only open-ended questions or questions with optional choices will be asked. This will allow the participants to think about the question fully and provide the answer that they think most appropriate.

11.4.1 Interview Guidelines

- Take breaks where necessary.
- Do not pressurise for an answer; wait for them to respond, if they take a long time ask if they would like the question rephrased.
- Find a place with few distractions to conduct the interview.
- Double check understanding e.g. You find maths challenging? Is that correct? You liked the use of coins in that game? Is that what you are saying/mean?
- If you struggle to understand a response, ask the carer or parent for help so there is no miscommunication. (Ask carer or parent if this will be acceptable prior to the interview).

11.4.2 Part 1: Icebreaker

- What have you done/are you going to do today?
- Are you enjoying Vale Plus/your job/class?
- Are you looking forward to our interview?
- What do you normally enjoy doing on a weekday/end?

(General small talk. Observe environment; if in the house, are there any obvious hobbies surrounding you? Football, t-shirt design, books etc).

11.4.3 Part 2: Observations

- Explain to participant what you expect them to do and what you will be doing.
  - (Observing and taking notes about how they find the software).
- Ask them to talk while they are doing the tests to vocalise if they are confused, finding it easy/difficult etc.
- Set up the current system you are observing on, let them familiarise themselves and maybe have a few goes.
  - (Observe familiarisation period). When they are ready start from beginning and observe the use of the system.
- Do another run through after they have completed the game:
  - How did you find that?
  - Why was it easy/difficult/confusing?
  - What would you change/keep the same?
  - Did you like the audio/use of keypad/use of pictures etc.?
  - Did you find it useful?
  - Would you use it again? Why?

- Requirements questions (In brackets is the requirement the questions links to):
  - How did you find the e-learner to understand and use? Easy? Hard? A Mix? (Usability)
  - How did you find the look of the e-learner? How did you find using the different functions like the menu and the money? Difficult? Easy? Confusing? Fine? (Interface)
  - Did you find the e-learner stressful at any point? (Stress free environment)
  - How did you find the feedback and instructions? Useful? Confusing? (Clear phraseology)
  - How did you find the shopping theme? Did you think the order of the game was ok? E.g. reading the shopping list, picking the items etc. (Realistic game logic)
  - How did you find having the main instructions and the shopping list always on the screen? Useful so you could remember or annoying and you would like to have been able to hide it? (Keep relevant instructions always visible)
  - How did you find the error messages, telling you that you had paid too much, too little or had placed the wrong items in the basket? (Helpful error messages)
  - How did you find the “Well done” message when you paid the correct money? (Good interaction throughout)

11.4.4 Prompts

- If they are seriously struggling or say that they cannot answers a question:
  - Why do you think you cannot answer the question? (Because there is no aid? Because you do not know how to work it out?)
  - What do you think would help you to be able to answer this question? (Calculator, tutorial, a visual aid [hand or counting blocks]).

11.4.5 Alternatives

- After using prompts:
  - Ask if they would rather move on to another question (you answer for them) or if they would rather you help them answer it for themselves.
    - (This will help prevent demoralisation as they are selecting their preferred method of continuation. If they opt for you helping them, observe how they learn from you so that can be adopted into end product).

11.5 End-User Interview Record

Below is an example of the end-user interview record. Justifications have not been included in this section as they are the same as stated in the Initial Interview Record section.

End-User Interview Record
Interview Information
Name of interviewer: **Date:** **Interview Place:** **Type of recording: (video/audio/written notes)** **Consent for recording: (yes/no)**
General Information of Interviewee
Interviewee number: **Age:** **Living situation:** **Interviewee experience: (qualifications, education, jobs, volunteering etc.)**

Part 1: Icebreaker Information
Icebreaker answers:

Part 3: Observations
Georgia Pocock – Shopping e-Learner file:///C:/Users/georg/OneDrive/Documents/Dissertation/e-learner%20code/index.html#
Observations: **Question answers:**

11.6 End-User Testing Synopsis

Overall the end-user testing was extremely successful. It highlighted the strongest and weakest points of the e-learner and the feedback was consistent. The main areas of improvement were unanimous suggestions (even though each interview was conducted separately) and are easily accomplished. Even though each person with DS is unique and their own person, they process information in a similar fashion (learning profile, mentioned in section 2.1); this was highlighted in their unanimity on their favourite parts, their struggles and subsequently their suggested improvements. In this set of interviews three new participants were introduced. These participants were to act as 'unbiased' users, having not been through the interview process before, and not used the pre-existing e-learners. There was no comparable difference in how the e-learner was received. As mentioned in section 1.1, two of the new participants were over the age of 30, one being 33 and the other 35. The participant at age 35 did not struggle with the game operation and process but did struggle to use the mouse and computer itself, a tutorial on how to use the computer was provided due to this fact. The participant who was 33 years old has a job that is heavily involved with using a computer and so this participant did not struggle. This demonstrated that although the e-learner is aimed at young adults with DS, it can be used by anyone who is capable of using a computer. Nevertheless, aiming the e-learner at young adults created a happy medium. It is age appropriate for the majority of people and has filled a gap in the available e-learners.

Overall, this e-learner is a great success. Although there are improvements identified in the below sections the e-learner was well received. Most of the feedback was positive, and when asked if they would use the e-learner again 100% of the participants said "yes!". [To view the consent forms please see Appendix 8 and for the end-user testing interview records see Appendix 9.]

11.6.1 Observations

As with the initial interviews these were conducted on a provided laptop, this was to ensure that no participant was at an advantage or disadvantage, and mitigated the risk of a participant not having the correct equipment for the interview. For the end-user interviews specifically it was essential to use the provided laptop as the e-learner is not yet responsive to changes in the viewport. Using a computer with a differing screen size could alter the e-learner layout, creating a confusing and unappealing design (this unfortunately also happens if the browser is minimised).

The provided laptop can be operated using the keyboard, mouse and/or touchscreen. This gave the opportunity to observe whether the participants preferred using the mouse or the touchscreen (as the keyboard was not appropriate for this e-learner) to operate the e-learner. After using both the mouse and the touchscreen: five of the six participants liked having the option, three preferred the touchscreen and two said they “did not mind” either way. The last participant is the aforementioned individual who was not entirely computer literate. They seemed slightly confused by the touchscreen and used a mixture of both touchscreen (to find and select the items) and the mouse (to select and pay the money).

All the participants either read the shopping list or the instructions first; if they read the shopping list first they then went on to read the instructions next. The instructions seemed well received and understood. All the participants were confident in what they had to do next and the process they had to complete. Two of the participants read the instructions and then started playing the e-learner straight away: this resulted in one participant forgetting to place the items in the trolley and skipping straight to the payment stage. They realised after paying for the first item that they needed to place the items in the trolley and started again. The other participants seemed to read the instructions one bullet point at a time. They would read the first bullet point, carry out the action and then move to the next bullet point and so on. This emphasised that bullet points were a good method of instructing in more ways than one. Bullet points were chosen to mitigate the risk of the instructions being verbose. Bullet points are a simple yet effective method of ensuring concise and clear text is written. However, it also provided the users with an understandable step-by-step guide on how to use the e-learner, that they could then refer to throughout the game.

The initial observation was that the users did not immediately register where the menu was, although, when asked they did not verbalise this as an issue. From this, the menu should perhaps be labelled to make it clearer and more apparent. However, this was not a major issue and not one participant needed to be told where it was.

When the menu was discovered, the majority of the participants had no trouble in operating it. One participant, however, was trying to click on the main menu row, but the main menu is only responsive when you click on the text:

Figure 76: Main Menu Not Responding on Row Hover

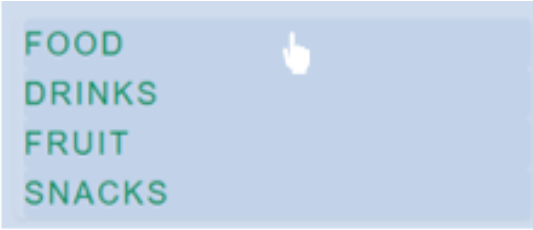
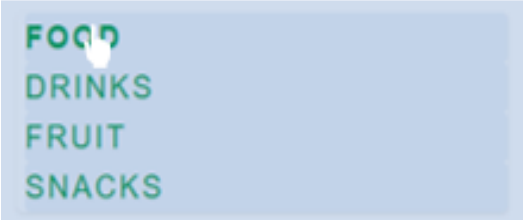


Figure 77: Main Menu Responding on Text Hover



It can be understood why this would be a confusing or frustrating trait and so even though only one participant struggled with this feature, it would be worth altering if a second iteration were to be made.

The ability to click on an item in the menu and have it appear in the trolley, and then click on the item in the trolley to remove it seemed intuitive to most of the users. Two of the users did not instantly register that you had the ability to remove the objects, which implied that there was a need for a small red 'x' in the top right corner of each trolley item to visualise the ability to remove said item. However, after some investigation the click to remove functionality was discovered with no obvious frustration or confusion present.

In relation to the above observation, two of the participants tried dragging the items into the trolley and attempted to drag the money into the hand. This demonstrated that for some users dragging is more intuitive than clicking. Although they did go on to figure out you simply clicked the item/coin, it was not their initial reaction. Therefore, having the option to click and drag might prove beneficial.

As mentioned in section 10.2 there was a restriction on the images that could be used within the e-learner for copyright reasons. This meant that some of the items that were initially wanted (e.g. a magazine section, toiletries section) could not be included. Due to this drawback it seemed that the menu titles, and the items within them, might appear confusing. However, they were all received well and after an initial search to see what items were within each section, every participant became accustomed to the items and soon were habitually going to the correct section first time.

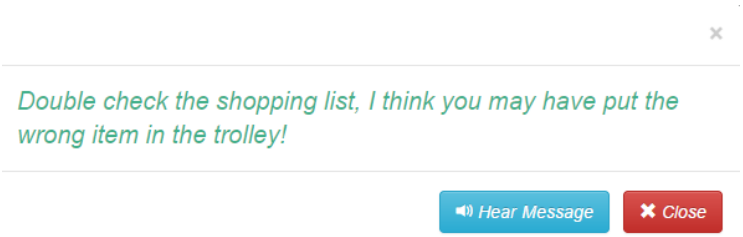
We then reached the stage in the e-learner where you had to pay for the items. Four out of six of the participants either did not know what they had to pay, or started paying for individual items based on the price(s) they could see in the shopping list:

Figure 78: Individual Item Prices

The fact that so many of the participants did not register the 'total', even though they had read about it in the instructions, highlighted that the total was not obvious enough. Once the total had been pointed out to them each participant seemed a lot less confused by what they had to do next, and started calculating what coins they needed to pay. The need to point out such a vital feature of the e-learner should not have happened, and so increasing the size of the 'total' or moving its position would be beneficial in a future iteration. In the original e-learner design (viewable in section 9.2) the plan was to have the total resting on top of the basket, near centre-screen. However, when the basket had to change to a trolley, the 'total' did not look aesthetically pleasing in that position and so it was moved. After observing the 'total' not being recognised, it can be established that it would be best placed somewhere more central so that it catches the attention of the user as the feature necessity overrules design.

Once the money had been placed in the hand and the 'pay' button had been pressed the user was met with either an error message or a message saying "well done!" and asking the user if they would like another go. Only one user accidently placed the wrong items in the trolley, and was met with this message:

Figure 79: Individual Item Prices



They immediately recognised their mistake, closed the message and altered their trolley accordingly. This was also the case with the messages expressing that the user had paid "too much" or "not enough" money. There was not a single user who got confused by the

message and if the message was met, each user closed it and reviewed the total and the amount they had paid. This established that the phraseology was clear and understandable. The final pop-up message a user could receive is the “well done” message. When every user received this message there was obvious elation on their face with either a smile or a clap. Only one participant did not automatically click “yes, please” for another go. When asked why they did not want another go this participant replied: “because it reminds me too much of school, I hated maths!” this was addressed by explaining how this could help improve their money skills when shopping and then asking the participant if they would like to continue or stop. Interestingly, after being told it could help their money-building skills they were more than willing to continue.

Surprisingly the ‘How to Play’ was not utilised by the users. As the instructions and game were simple and clear enough it was not a necessity. However, it is always helpful to have it in case a user needs further instruction. Therefore, the participants were asked to review the ‘How to Play’ so that its effectiveness could be observed. It was found that the screenshots taken as visual aids to help the user understand the text needed to be altered. As the screenshots had text within them, four of the six users read the text within the screenshot as well as the ‘How to Play’ text. Therefore, having the text on the screenshots blurred out would prove useful. Three of the participants struggled to navigate the ‘How to Play’ as they could not find the arrows to move the ‘How to Play’ to the previous or next section. From this it was noted that the users would benefit from having the arrows either underneath the images or having buttons which stated “previous” and “next”. Finally, the last ‘How to Play’ improvement would be to stop the repetitive loop. Currently, the ‘How to Play’ automatically goes to the first slide when you click the next arrow after the last slide. This creates an endless loop and was confusing to several of the participants.

11.6.2 Requirement Question Answers

In this section the overall views of the participants on each of the requirements they were questioned on (stated in section 11.4.3) will be expressed. Their answers and opinions will be briefly paraphrased and then it will be stated whether that requirement is a success or failure.

The general consensus on the *usability* of the e-learner was that it was “easy”. The only real struggle was with participant 4 who struggled to operate the computer itself. All participants said that the images helped with the use and understanding of the e-learner. Participant 6 even stated that the use and process of the e-learner is “really, really clear!” They all stated that they found having the shopping list really useful so that they could remember what they needed to buy. Overall, the feedback has been positive and that the usability requirement has been achieved.

Again, the *interface* was enhanced through the use of images, all of the participants stated that they liked the images being used on the shopping list and menu as it made the items easier to identify. They liked how you could place the items in the trolley so you could see what you had bought “like in the real shops”. One participant highlighted that the use of

images for the coins really helped them to identify what coins they needed and which ones they had already paid with. Interestingly, they went on to say that it was the shape of the coin that aided in the recognition. One participant detailed that they found the images of the coins useful because they "recognised the shape of the money rather than the denomination". Participant 6 highlighted that the use of bright colours made the e-learner more fun. Therefore, this interface requirement is deemed a success.

All the users found the e-learner to be understandable and "easy to use". This encouraged and allowed for a *stress-free environment*. The only time any inclination of distress was observed was with participant 4, who was getting frustrated by the operation of the computer mouse. After demonstrating the touch screen, however, the participant quite obviously relaxed. The participants found the theme and style of the e-learner to be appropriate for their age and their day-to-day activities. Overall, this was obviously met through the observations and when asked, four of the participants said that they did not feel stressed whilst playing the e-learner, whilst the other two participants said they did, but because of the mathematics not the e-learner itself. From these findings, the stress-free environment requirement can be safely declared as a success.

As can be seen from the observations, there was no evident confusion on what the pop-up messages were telling the user, and the instructions were mostly well understood (*clear phraseology)*. Participant 1 stated that they thought the e-learner contained a nice amount of text – "not too much, like the others". This was very encouraging to hear. Two of the participants opted to have the text read aloud using the audio assistance. This appeared to be an appreciated feature. The audio assistance on the pop-up messages was well understood. However, as expected, the audio assistance on the instructions was too fast and the participant asked if I could read it to them instead. This highlights an issue with the audio assistance; the phraseology itself was well understood throughout the e-learner by the participants and so this clear phraseology requirement has been successfully achieved.

The *realistic game logic* appeared to be well received as the shopping theme was a massive success. All the participants responded positively when asked about the theme of the game. Each participant related the theme to their personal experience, participant 2 stating they enjoyed putting the items in the trolley "like at Tesco's". The only disapproval the game logic received was from participant 5 who requested that DVDs and video games be added to the menu because they "don't go food shopping". As the only negative comment was a future suggestion rather than a current error the realistic game logic requirement is a success.

When asked if they found having the instructions visible at all times useful, all of the participants said yes. Five out of six of the participants elaborated to explain that if the instructions were hidden they may not know what to do, or in the words of participant 6 "lose their thread". The instructions were needed for referral so that the user could ensure that they were using the e-learner correctly. Again, this requirement of having the relevant instructions always visible has been achieved.

As highlighted in the observations, the error messages were understood by all participants. From reading the error messages, they identified what they had done incorrectly and

immediately closed the message and adjusted their actions accordingly. When asked if they found the error messages useful they all said in various terms that they did; three of the participants went on to state that they liked being able to have another go at getting the correct answer. The helpful error messages requirement has been successfully achieved.

Similar to the phraseology and the error messages, the participants found the interaction throughout clear and comprehensible. They understood what they needed to do and where they went wrong. The participants all chose the "well done" message as their favourite; they found it motivational and it made them "happy to know they got the answer right". One participant specified that they liked being asked whether they wanted another go, so that they could choose for themselves when they wanted a break. This requirement of good interaction throughout the e-learner was also successfully accomplished.

11.6.3 Identified improvements

Although the issues identified with the initial prototype of the e-learner have been explained in section 11.6.1, a condensed list of what the main improvements should be if a second iteration were to be conducted is provided below.

- Add a title to the menu making it easier to identify.
- Have the entire main menu row selectable, instead of just the text. This will improve the usability.
- Have the option to click or drag the items into the basket and the coins into the cashier's hand.
- Remove the price of items from the shopping list (show just the items and item image) to prevent confusion on what the participant should be paying.
- Increase the size of the 'total' and/or move the 'total' to a more central position.
- Add a red 'x' onto the corner of the items in the trolley, increasing the certainty that those items can be removed.
- 'How to Play' needs a more visually obvious method of directing the user to the previous or next slide.
- 'How to Play' needs to blur the text that is visible on the screenshot visual aids to prevent confusion on what text should be read.
- The loop cycle on the 'How to Play' needs to be stopped. When a user reaches the end of the 'How to Play' it should not continue back to the first slide when the user clicks the next arrow.
- Audio assistance needs to be slower and preferably, but not essentially, less robotic.

11.7 Untestable Requirements

Unfortunately, a couple of the requirements are not testable within the time frame allocated. Scalability and maintainability are two requirements in any development process. Maintainability was tested using a test case. This has been achieved through evidencing that the code has been commented. However, as this is an individual project, there are no other persons to evaluate the maintainability, and so it can only be compared to personal standards and levels of understanding. Therefore, it could be a biased test as the code and scenario are already known. Maintainability is encouraged to provide aid and understanding to new people on a project. Consequently, the only way of truly testing the maintainability would be if someone were to continue with the project in the future. Scalability is another requirement that would also need to be tested in the future. The e-learner contains all the anticipated functionality and so was created with each feature in mind. Current functionality becoming compromised if new functionality was added is, again, a requirement that could only be tested if this project were to be developed further with additional features.

11.8 Testing Summary

Overall, the test cases and end-user testing have proven that this e-learner prototype is a great success. Although there are various noted improvements, all the essential requirements and most of the desirable requirements were achieved (overall, only failing to meet two requirements). The main aim of this project was to create an environment where the user could understand and enjoy using an e-leaner without feeling patronised, confused or stressed. As proven by the above results this was accomplished and from that it can be concluded that this project has been successful.

The languages and frameworks that were used for this project proved to be the right choice. They enabled the completion of the project in the short timeframe allocated and required less designated 'learning time' than other languages would have. Due to past experience with HTML and CSS and the minimal experience with JavaScript, Code Academy was an efficient and satisfactory way of self-teaching what was needed to be understood in a short amount of time. The popularity of these languages resulted in endless frameworks and online advice and guidance.

There are no regrets on the chosen methodologies (see section 4.2). Obtaining the requirements through the interviews established a real insight into the needs of the users. Although a thorough search into the learning profile of a person with DS had been conducted, a true understanding of the extent to which the users can sometimes struggle was not attained. This was highlighted in 'good practices' and 'bad practices'. Through this, a true insight into how the e-learner *needed* to act and respond in order for the project to reach its goal was achieved. The e-learner having to be intuitive, having no confusing behaviour and to be error-free were imperative requirements. The methodology used allowed the opportunity to get even more personally involved in the issue, which led to increased motivation to complete the e-learner and achieve the outcome.

12 Future Work

The work accomplished within this project has been great progress and it provides an excellent basis for future development. As there were limited e-learners designed specifically for these intended users the potential for further work is vast: whether that be through expanding on what this project has created or expanding to different areas of learning disabilities or devices.

Several future improvements have already been highlighted by the users themselves, in section 11.6.3. To avoid repeating those improvements, the below subsections explore the possibilities for further development of this project that have not been previously identified.

12.1 Cross-browser

As this was a failed requirement it is only natural that it gets listed as a future development. As of 2012 the most common web browsers are Internet Explorer, Firefox, Chrome, Safari, UC Browser and Opera. (Statistics can be found in Appendix 7) [27]. Currently, the e-learner is only fully compatible with Chrome, and although Chrome is noted as the most popular browser, the other popular browsers accumulate 37% of users. Having the e-learner work on multiple browsers will increase its usability and make it accessible to more users [28].

12.2 Further adaptability

This future development is the only other failed requirement. Neither the implementation of a volume control feature or the ability to choose the amount of questions you will be asked were achieved. Volume control was a feature that was implemented unsuccessfully and therefore removed. If more time had been available, the appropriate amount of time could have been allocated researching a solution for this failed attempt. However, as there was a time restriction, the time was deemed better spent completing the essential requirements. Through the research mentioned in section 8.4.3 sometimes, due to hearing aids or grommets, the intended users can have sensitive hearing. If they are not computer literate they may not have the knowledge to control the computer volume and so including a volume control feature within the e-learner itself would prove beneficial. The ability to choose the amount of questions is simply a psychological feature, the user can see the end in sight, providing more motivation to complete the task at hand.

12.3 Update the £1 coin

As explained in section 10.2, the new £1 coin was not incorporated into the e-learner as it was only a week or two old when the end-user testing was completed. A visual test was conducted to observe how many people with DS recognised the coin, and out of 18 people only seven did. Therefore, it was decided that the coin was too new and the old £1 coin image would remain. However, if this e-learner were to be developed further updating the £1 coin image would be appropriate. Time would have allowed the users to familiarise themselves with the new coin and so it would be more appropriate to update the images. This would be a continuous development as more new coins and notes are released.

12.4 Difficulty levels

The aim of the project was to create a mathematical e-learner that was usable and understandable for users with DS. More specifically, an e-learner that was not designed visually for a child, allowing the young adults with DS to use and understand the e-learner without feeling patronised. However, the purpose of the e-learner from the user's perspective is to improve their mathematical ability, in this instance in the form of money. The inclusion of difficulty levels will allow the users to constantly develop their learning and continue to challenge themselves. It would also widen the user pool as people of all capabilities could use the e-learner and simply play at their own level of ability.

Having difficulty levels could include functionality such as more money – including a 1p coin, 2p coin, £5 note, £10 note etc. This will encourage the calculations of bigger sums of money as well as more common combinations, such as £9.99. The current prototype is a fantastic stepping stone, but this would be the next step. With these added monies a combination of more expensive items could be included. A final step that could be taken on the more difficult levels could be removing the total so that the user has to calculate the combined price of the items without assistance.

12.5 Expand to accommodate for various disabilities

Due to the time restriction on the project there was a need to refine the scope and so the e-learner was only designed for users with DS. However, there are a multitude of people with other disabilities who are also prevented from having the opportunity to practice their mathematical skills due to a lack of accessible e-learners that accommodate their needs. Through the interviews, it was observed how happy the participants were to use the e-learner. They experienced minimal struggle in understanding and operating the system and had obvious elation at being able to practice their skills, especially when they got the answer correct. This demonstrated that it had not been truly realised the impact this e-learner would have on them. Therefore, this is probably one of the more imperative future improvements. There is a severe lack of understanding on disability-friendly applications and an even bigger absence of available, free resources.

12.6 Advanced audio assistance

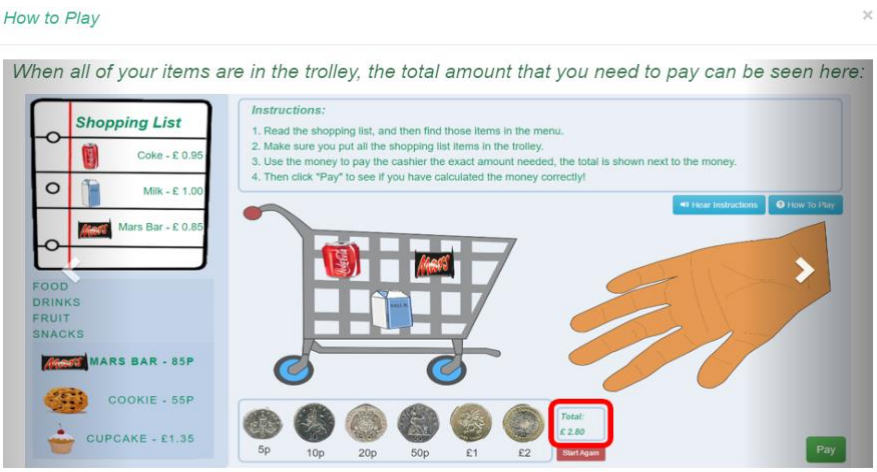
Although audio assistance was included, it could be improved upon to accommodate illiterate readers, or readers who are visually impaired. With the prototype you have to click the “Hear X” button to have the text read to you. Currently, there is only audio assistance for text heavy sections. However, some users may require audio assistance for everything. To avoid the interface becoming cluttered with multiple “Hear X” buttons a user who requires this functionality for all text would benefit more from having the text read automatically on hover.

The audio assistance could also be improved upon in terms of voice and speed of talking. As mentioned in section 10.2 there were concerns that the voice used was too robotic. This retracts from the humanity of the audio assistance and could prevent the user from feeling motivated as they cannot hear any emotion. The voice talks at an extremely fast pace, only seeming to take breaks at commas and exclamation marks. This would need to be fixed in future work to achieve a slower pace of talking that the users will find more beneficial.

12.7 More understandable ‘How to Play’

Although the current ‘How to Play’ fits the specified criteria of visual aids and minimal text, there is still room for improvement. The option to incorporate a video ‘How to Play’ was decided against as it cannot be time controlled, therefore it might run too fast for some users or too slow for others. Having the slide show appearance is extremely beneficial for that reason. However, including some animation would enhance the understandability of the instructions. Currently, it is not entirely obvious what functionality is being referred to, especially on the smaller features.

Figure 80: ‘Total’ Highlighted



Through making the red box flash, for example, attention would be drawn to that feature and increase the user’s understanding.

13 Reflection

In this section I will discuss the changes that have occurred throughout the duration of the project, I will then go on to explain the reasoning behind those deviations. This section will also provide a reflection on how this project and the process to develop it has affected me personally. I have reflected slightly throughout the sections within this report, therefore in this section I will highlight the main areas of improvement I have made and the areas of the project I would change or improve upon in hindsight.

13.1 Project Reflection

In the initial plan I stated that I would produce and distribute a questionnaire for the parents. This would have allowed me to gather information from the parents' perspective on their children's abilities and needs. However, I decided to discount this process; after more careful consideration the conclusion that it would not add enough value to the project was met. The parents were likely to be biased in their opinions (see section 8.2) and may not be fully aware of what their children's needs were. Although I still believe this would have been extremely interesting to include, due to the time constraint it was not a practical addition as the time was better spent observing the participant's themselves to witness first-hand what their requirements were.

As mentioned in section 10.1 PHP was made redundant as the e-learner did not necessitate a database, the evaluation of inputted data, cookies, or forms. I could have opted for a language such as Python but as my previous experience with said language was not formidable, it was not a risk I was willing to take. With JavaScript, I had the capability to self-teach using Code Academy, I had Bootstrap to aid in the implementation and I had colleagues, skilled in the language, at my disposal to tutor me. Therefore, in terms of available time and enabling me to meet the requirements of a dynamic HTML page and content that interacts with the user, JavaScript seemed the best option.

Before conducting more thorough research, I was narrow minded enough to only consider a generic mathematical e-learner which could then aid the user's financial ability. However, after finding the pre-existing e-learners and discovering e-learners that were centred around the improvement of money skills I then considered the possibility of having a shopping e-learner that focussed primarily on building the user's financial skills. In section 8.1 it was concluded from the initial interviews that a money based e-learner would prove the most beneficial. The aim of the project was simply to provide an e-learner that the users could utilise with ease, that was not originally designed for children. This would enable them to work on their mathematical skills in an environment that they understood and could operate with ease without feeling like a child. The scenario of the e-learner was not essential to the project's success: the design, interface and interaction was. Therefore, basing the e-learner around a money exchange was purely a simple nicety to incorporate that encouraged the logical layout of the e-learner whilst simultaneously providing an added benefit to the users: a chance to improve an essential skill.

Although I had considered researching into Neilson's Heuristics and incorporating the findings into the design I had not considered conducting a Heuristic evaluation. I decided to incorporate this as a means to validate the design and ensure I was not overlooking a Heuristic violation. The Heuristic evaluation allowed me the opportunity to demonstrate that I had considered the Heuristics whilst simultaneously adding a proof of concept to the design. From this I could confidently start the implementation without worrying that I was creating unnecessary functionality or missing out key features and design.

Test cases are an addition to the project plan. I did not include them in the initial plan due to a judgement error. I simply did not consider the fact that I would need to personally test the functionality to validate that the features were complete and the requirements had been met before being able to conduct the end-user testing. As I progressed through the implementation it became apparent that I had massively overlooked this part of the process as it is a step that you take naturally. Therefore, I have added in the test cases to evidence that I did in fact test the product before releasing it for end-user testing. From this I have learnt how easily generic steps can be overlooked.

As the main purpose of the project was to create an e-learner that someone with DS could use, understand and operate with ease, I thought it was important to ensure that this criteria was met from all angles. Initially, the end-user testing participants were going to be the same participants from the initial interviews as I knew they had experience with e-learners. However, I chose to include an additional three participants in the end-user testing. Whilst seeking out these new participants I ensured they had little to no experience with e-learners. This would allow me to justly test, from an unbiased perspective, whether the e-learner was truly intuitive, understandable, stress-free and operable for a person with DS. I believe that this change from the initial plan was the most valuable as it provided the opportunity to validate the project's success.

The aim was to complete more than one round of end-user testing. This would have enabled an iterative approach to the prototype, allowing improvements to be made each iteration until it obtained a unanimous approval. However, due to changing the language choice from PHP to JavaScript I had the unexpected task of having to teach myself language I had minimal experience with instead of simply refreshing my mind on one previously learned. As I used Code Academy to teach myself JavaScript and refresh my memory on HTML and CSS I had to follow their process. Whilst using Code Academy I soon learned that you could not move on to the next lesson until the current one was completed. This meant that, for example, I had to go through each lesson on how to change the colour of the background three separate ways before I could move on to the serious lessons. Due to this I was delayed in my learning process as I had to re-learn the basics I already knew before I could access the lessons that I needed. This resulted in the implementation and testing being allocated less time than intended. To accommodate this change in the project timeline I had to compensate: as the multiple rounds of end-user testing was a desirable concept, not essential, I decided to change the process to just one iteration.

Similarly to the removal of the questionnaire, the process of interviewing people with DS and those without was initially included as an interesting comparison rather than an essential part of the project. It did not contribute enough to the project's success for me to

keep it in the project. As mentioned in section 3.6 the ethical approval process was delayed to the extent that the interviews could not be conducted until a week or two after they had initially been planned. This resulted in having to make up for lost time. Although the comparison of users with DS to those without would have aided in validating the need for such an e-learner, it was not vital to the project's success. The research conducted already evidenced the difference in user requirements for a person with DS (e.g. visual aids and audio assistance) and so the extra validation, although nice, was not needed when faced against a reduced timeline.

13.2 Reflection on Learning

When starting this project my main concern was the implementation. There is a massive stigma around Business Information Systems students and their coding ability. However, this project was based around a topic that I felt extremely passionate about, and so I knew that it would provide me with the motivation to complete it. The implementation ended up being the most frustrating but liberating part of the entire project. Each accomplishment provided me with a jolt of motivation and pride. I believe this taught me a valuable lesson; self-doubt is never useful, and if you want to achieve something you simply need to find the right tools to allow you to do so. Through research and talking to my colleagues I discovered Code Academy and Bootstrap, without which I would not have completed the implementation in time.

As I completed a placement year I was confident in my project management skills. However, this project taught me that every experience is invaluable and teaches you a new lesson. Although I strongly believe my placement experience benefited me, I was still prone to overestimating the time that I had available. This is where good communication between myself and my supervisor became vital. He highlighted to me that although some of my plans would provide interesting findings, they would encourage a scope that was too big. It was through his advice that I managed to maintain the scope to a practical size. We upheld consistent meetings which provided me with the opportunity to see a different perspective on the project. A few times this resulted in a change of direction or removing pieces of work that were unnecessary for the scope of the project.

Although I am extremely pleased with the outcome of the project and its success, I would change the approach were I to redo the project. If I had been allocated more time, I would have allowed myself the opportunity to delve into different methods of research. As I volunteer heavily with organisations surrounding people with DS I have people and resources available that I was not able to utilise within such a short amount of time. I had to think of the long-term goal, and being aware that I needed to dedicate more time to the implementation I could not risk waiting for my schedule to align with these individuals. For that reason I was restricted to just the available online and book research. This was extremely limited and resulted in the findings being somewhat lacking and most definitely outdated.

Due to the timeframe, I had to prioritise the essential sections of the initial plan. For this reason I decided to remove the interviews with people without DS. Although I believe this would have validated the need for my project further and would have produced interesting results, it was not crucial to the success of the project. I believe the scope limitation removed several potentially interesting findings and contrasts that could have been made.

Additionally, I would have liked to have had the opportunity to incorporate the identified improvements that were highlighted in the end-user testing. As the issues identified were fairly minimal, I believe I could have achieved this if I had started, and therefore completed, the implementation sooner.

Overall, I am extremely pleased with the process and development of this project. Although there is room for improvement, it has been a great success. I was dubious about the success of this project at the start as I did not have enough faith in my own abilities, and I am proud that I have proven myself wrong. I believe that I have demonstrated originality and creativity in the project; I have identified and solved a serious issue that not many people are openly aware of. I have used skills that I have gained throughout my degree and some which I have had to re-visit or simply teach myself in order to accomplish this project. I believe these factors have evidenced my initiative and ability to challenge myself. The e-learner reached all expectations and requirements and has provided an easy, enjoyable and stress-free environment for the users to develop their own learning.

14 Conclusions

As with any project, mine has changed direction throughout its lifespan. I have altered the methodology, removed and added tactics such as questionnaires, a Heuristic evaluation and less rounds of end-user testing. This is down to over-estimating the scope of the project, and the learning process I have gone through during the project. However, at the beginning of this project I set a core goal as well as a list of essential objectives.

My predominant aim was to "develop a mathematical e-learner that a person with DS can use at ease. This would entail an e-learner that they find intuitive and do not struggle to understand or operate." I believe that this core goal has been comfortably achieved. As can be evidenced by the end-user testing, all the participants found the e-learner easy to use and stress-free. Several of the participants started the interview not knowing what to expect, but two participants (participants 2 and 6) were vocal in their worry and their uncertainty was evident. However, all participants were content and proud when the interviews concluded. There was an obvious preference to using the e-learner with the touchscreen instead of the mouse. The e-learner itself was intuitive, and in areas where it was slightly ambiguous the instructions provided clear and understandable guidance. I was acutely aware that the observations could be perceived as biased, which is why I incorporated open ended questions into the interview to ensure that they were not leading. The responses to these questions (which can be viewed in Appendix 9) are evidence that this ultimate goal was met and I am confident in declaring the project a success.

As well as my core goal, I also listed a set of objectives that I deemed as essential to meet in order for the project to be a success. These were defined as follows:

- Research into DS; common conditions, learning methods and communications that could help me develop the requirements.
- Research into pre-existing e-learners that could highlight requirements and potentially provide me with design or functionality ideas.
- Gather requirements directly from the intended users.
- Learn whether a simple mathematical, financial or mixed e-learner would be more beneficial (requirement gathering).
- Based on the aforementioned requirements build a set of functional and non-functional requirements.
    - These will be labelled as essential or desirable requirements. Essential requirements are those which need to be met and desirable are the requirements that are not necessary but would be a nice addition.
- Explore the potential tools and/or languages that can aid in the implementation of the e-learner.
- Design and implement at least one prototype of the e-learner.
    - This prototype will need to include all of the essential requirements identified in the previous objectives and as many of the desirable requirements as possible.
- Conduct at least one round of end user testing for the first iteration of the prototype to ensure that requirements are met and the project is successful.
- Analyse the end user feedback.

- Reflect on the project and evaluate how I could have improved and how I can develop the project further.

The first objective of researching into DS was completed, but not in as much detail as I would have liked. This was due to a lack in the available materials and the time restriction. The time restriction meant that I was limited to available resources such as online websites and studies. However, the majority of this research was outdated and provided little variation in the study outcomes. This resulted in a lot of the findings having to be achieved through my own investigation.

A lack of appropriate, pre-existing e-learners prevented me from reaching the second objectives full potential. Although five e-learners were found and used, none of these e-learners were created with their target audience being people with DS. This highlighted a further demand for the project, and although e-learners were found, it would have been more interesting to test currently available e-learners with the relevant target audience.

Having multiple rounds of end-user testing to achieve an iterative approach to the e-learner was the only other objective not attained in its entirety. It was stated that a minimum of one round of end-user testing had to be conducted. Although this was achieved, I believe having multiple rounds and reaching that iterative approach would have increased the richness of the project. The improvements could have been implemented as they were not that strenuous and it could have been truly tested whether they would have allowed for a faultless e-learner or if more improvements would have arisen. Having at least a second round of end-user testing could have been a neat close to the project. However, I believe due to the time and scope restrictions, completing one iteration was a fantastic achievement and the outcome of the testing proved it to be a great success.

Although some objectives have been delivered in less detail than anticipated due to circumstance of time or available material, they have all been met. I am happy with the objectives set and the outcomes that they have enabled. I believe my core goal and individual objectives accommodated the success of this project. They enabled me to maintain my reasoning throughout this project and prevented me from going off track or developing my scope to a level that I would not be able to achieve. Overall, I am extremely happy and proud with the outcome and success of this project.

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