Creating a Tool to Help Students on the Software Design and Modelling Course Identify Errors in Unified Modeling Language (UML) Diagrams

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4th Year Project Report
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2023

Abstract

Unified Modeling Language (UML) diagrams are used to visualize and communicate concepts and designs for software between developers. Whilst interactive teaching tools for UML do exist, due to the broadness of the field these are not majorly useful to educational courses that cover only a specific range of content from UML such as the Software Design and Modelling (SDM) course taught at The University of Edinburgh. This dissertation aims to create a tool to specifically aid students on the SDM course to revise for their mid-term lab assessment covering UML. This is done by using a learning from errors approach and an online quiz format to help students become better at spotting errors in UML diagrams.

The dissertation concludes that students liked using the tool for revision, found it an effective form of revision, and found it easy to use. This means the use of an online quiz with a learning from errors approach was a successful tool for the revision and further education of students on the SDM course in terms of their UML diagram knowledge. Multiple improvements and extensions were also suggested by the students and these, along with other ideas noted throughout the project, are listed as topics for future work.

Research Ethics Approval

This project obtained approval from the Informatics Research Ethics committee.
Ethics application number: 343512 (rt #7140)
Date when approval was obtained: 2022-11-22
The participants' information sheet and a consent form are included in the appendix.

Declaration

I declare that this thesis was composed by myself, that the work contained herein is my own except where explicitly stated otherwise in the text, and that this work has not been submitted for any other degree or professional qualification except as specified.

(*Iona Cooper*)

Acknowledgements

Firstly, I would like to thank my supervisor Professor Perdita Stevens who supported and guided me throughout this project. Her passion to create this tool in order to improve the experience and education of the students on the Software Design and Modelling course was a huge motivator in my work. In addition, I would like to thank Dr Heather Yorston for providing me with initial educational resources.

I would also like to thank the 2021/2022 and 2022/2023 Software Design and Modelling students who agreed to be involved in this project. Whether it be through providing data or giving their time to provide evaluation, it wouldn't have been possible without them.

Finally, I would like to thank my friends and family. It is the greatest achievement to have reached this point in my university career and it was with their constant encouragement and support that it was possible. I will always be grateful.

Table of Contents

Chapter 1

Introduction

1.1 Motivation

The Unified Modeling Language (UML) is a language widely used in the technology industry to aid the visualisation and communication of software designs and concepts through standardised diagrams. There are many resources available to aid the teaching of UML - documentation, tools to create diagrams, and quizzes - however spanning such a broad field it is challenging to find interactive teaching tools covering course-specific content.

The Software Design and Modelling (SDM) module at the University of Edinburgh aims to educate students about the design and modelling stages of software development and so covers UML focusing on a number of the most commonly used diagrams. The course assessment is split equally into a final exam covering all course content and a mid-term lab assessment which tests student knowledge of using UML in the design stage of software development.

The course organiser (and supervisor of this dissertation) observed that for revision for the mid-term lab assessment, when as previously mentioned a lack of existing specific teaching tools are available, an interactive tool targeting the detection of errors, specifically those commonly made by students on the course, in UML diagrams may be of use to students. This dissertation aims to create such a tool using past lab assessment questions, student answers, and feedback in a 'learning from errors' approach and so creating a tool unique to the SDM course and its students.

1.2 Research Questions

Although this dissertation's overall objective is to create a tool for students on the SDM course to practice detecting errors in UML diagrams, this can be broken down into following research questions:

- **RQ1:** What teaching tools currently exist for UML diagrams?

- **RQ2:** Is 'learning from errors' an effective teaching approach, particularly regarding UML diagrams?
- **RQ3:** How may an effective teaching tool for UML diagrams be created?
- **RQ4:** Do students on the Software Design and Modelling course find the new tool effective in regards to their education of UML diagrams?
  - **RQ4.1:** Do students find the tool improves their knowledge and understanding of UML diagrams?
  - **RQ4.2:** Do students want to use the tool?
  - **RQ4.3:** Do students find the tool easy to use?

1.3 Dissertation Structure

A detailed structure of the dissertation is as follows:

- **Chapter 2 Background Research** This chapter examines the current landscape of teaching tools for UML models, the efficacy of the planned project approaches -learning from errors and online quizzes, and how best to proceed with the design and implementation of the tool for the SDM course.
- **Chapter 3 Low-Fidelity Prototype Design and Evaluation** The dissertation will then move to the development of a low-fidelity prototype in this chapter. This prototype will be a non-functional design of the planned user interface. To evaluate its suitability, a focus group with prior SDM students is held to ascertain their opinions of the prototype (and main tool concept). Feedback is then analysed and necessary changes are implemented.
- **Chapter 4 High-Fidelity Prototype Design and Implementation** Following the low-fidelity prototype, a functional high-fidelity prototype is developed. This is created using JavaScript and HTML and hosted using GitHub pages. The prototype is a fully operating version of the final tool and is released for the use of the current SDM students to revise for their mid-term lab assessment.
- **Chapter 5 High-Fidelity Prototype Evaluation** Following the release of the high-fidelity prototype, students will have the option to evaluate their experiences with the tool using an online questionnaire. The feedback drawn from the questionnaire is then analysed and used to propose future developments for the tool.
- **Chapter 6 Conclusions and Discussion** The dissertation will conclude with a discussion on the outcome of the proposed research questions as well as the study's limitations and future impact.

Chapter 2

Background Research

2.1 The Unified Modeling Language (UML)

2.1.1 Application in the Software Development Industry

Software modelling is "an essential part of the software development process" [12]. Such models are used to illustrate software designs [34] and they are of significant use to software developers for communicating and visualizing ideas. The Unified Modeling Language (UML) "represents a collection of best engineering practices that have proven successful in the modeling of large and complex systems" [30] and sets standards that may be used to create software models.

2.1.2 Prevailing Teaching and Educational Tools

Currently, tools that can be used to create UML models such as Eclipse Papyrus [29] and LucidChart [22] are commonly used to help teach about UML diagrams. Further, there is extensive documentation of UML available online which can be used for learning and revision [30]. Interactive online teaching tools such as quizzes are also available [14], however, as there are 14 types of UML diagrams [26], they usually cover a broad field. Whilst they may be useful for students' general revision of UML, due to the specific content and structure of the questions asked in the SDM mid-term lab assessment, a custom teaching tool targeting SDM students specifically would be valuable. By using the previous year's mid-term lab assessment data the tool can be uniquely tailored to the SDM assessment style and attitudes of students on the course.

2.2 Learning from Errors

2.2.1 Synopsis

Learning from errors is the basic idea that when we make an error this provides an opportunity for us to learn. One study went as far as to describe errors as 'essential' for learning due to them having "a pivotal role in improving learning and instruction"

[37]. In addition to this, it has been found that when students have a positive attitude towards making errors in their learning this is "directly predictive of high academic achievement" [21].

However, many students, for a variety of reasons, can have very negative reactions to making errors in their work [37] that are not conducive to learning. This leads to a conundrum - errors are a great way for students to learn however can cause emotions detrimental to learning. A solution is to utilise common student mistakes in a learning tool for students, helping to teach them but avoiding the negativity associated with students making errors themselves and so in effect allowing the students to learn from other people's mistakes. This is the kind of tool we will be creating.

A study conducted with a class of eleventh-grade students to observe their reactions to learning from errors [44] gives two examples of such tools. The class were given tasks each using one of the tools employing a learning from errors approach - one involved the presentation of a question with an incorrect answer and gave the student the role of explaining why the answer was incorrect, and the other provided incorrect statements on a subject and asked students to identify and explain the error in each statement.

2.2.2 Efficacy of Application in Educational Tools

Studies regarding learning from errors, such as the one previously mentioned involving the eleventh-grade class [44], have so far yielded positive results [44], [3], [32]. In our earlier example, the class showed a very enthusiastic response to the learning from errors approach, they felt the tasks had encouraged them to be more mindful regarding the more specific detail of their answers and had helped them to better grasp the overall concepts the tasks were teaching.

This is not the only study to conclude that learning from errors leads to students gaining a more thorough understanding of core topic concepts. A study conducted into the use of learning from errors in the field of mathematics concluded that errors can be used as "a starting point for creative mathematical explorations" [3]. They suggest that examining the reasons behind student errors opens up new perspectives and discussions that overall bring about a greater understanding of the topic.

Interesting results were also obtained in a study conducted with a group of seventh-grade mathematics students [32]. The group was split into a control group, who were taught conventionally, and a treatment group, who were taught using learning from errors. Both groups, who were being taught about the same subject, were given a test as soon as they had learnt the material and a test on the same material 6 weeks after the teaching. The groups scored similarly in the first test, however, in the latter test the treatment group did considerably better indicating greater retention of knowledge. This is a significant finding concerning the creation of our tool as, whilst the tool should aid the students' performance in the mid-term lab assessment, the main goal of the course is to teach students and therefore we would like the students to retain as much knowledge as possible.

Another study, conducted with seventh and eighth grade students, drew conclusions suggesting students' prior knowledge was a significant factor in how well tasks employing

learning from errors helped each student [15]. Specifically, they concluded that students who felt the benefit most were those who had considerable prior knowledge of the subject area rather than those who did not know the area as well. This is a particularly relevant finding given the tool will be being used for revision purposes and so we will be working with students on the SDM course who have prior knowledge and understanding of the tool's content.

It has also been found in a study into students' programming errors that closer examination of these errors prompted a deeper understanding of them leading to the development of better teaching materials [5].

2.2.3 Prior Usage in Higher Education Courses Examining UML

A particular study, conducted at Katholieke Universiteit Leuven with a group of masters students studying a module on UML class diagram design [1], trialled a learning from errors approach. They analysed the solutions to given exercises that students in the 2017 class had submitted and identified the most error-prone areas. They then altered the way the course was taught the next year in 2018 to target these areas more than the previous year. When comparing the results of the 2018 student solutions to those of 2017 they noticed an improvement in nearly all error areas that they had previously identified.

Another investigation into the impact of teaching using learning from errors in UML diagrams was conducted at the Shamoon College of Engineering with 45 students studying a course also involving learning about UML diagrams [35]. The study involved the students working in pairs to design UML models appropriate for a given scenario before submitting these to the teacher, who then randomly distributed these back among the students who in turn proposed feedback for the diagram they received. The students then received the peer feedback given to their initial submission and had to redo their diagrams before resubmitting them. An analysis of the diagrams before and after the feedback showed that initially all students were making at least 3 mistakes whereas after feedback some students made no errors with over half making only 1 or 2 errors. The key takeaway from this study for our project is that although the feedback given by other students may not have been correct or thorough, the process of error analysis by students helped them learn and subsequently improve their own diagrams.

Whilst neither of these examples is an exact implementation of the concept for our learning tool, we can draw useful information from their findings. Firstly, the identification and targeting of errors in previous students' work has proven effective for teaching current students in the software modelling field. In addition to this, asking students to consider the correctness of their peers' work before reconsidering their own significantly reduced the number of errors made by students.

2.3 Learning Tools

2.3.1 Efficacy of Online Quizzes as Revision Tools

The use of online quizzes has, in prior studies, been found to be an effective form of revision [43] [24] [13]. They have been found to motivate and engage students (with them giving very positive feedback and even going as far as to call them 'enjoyable' [43]) as well as lead to a direct increase in students' academic ability compared to students not using quizzes as a form of revision [43].

A study conducted at the Tel-Hai College in Israel looked particularly into students' attitudes towards online quizzes [6]. Researchers found that not only was student performance in online quizzes directly predictive of exam results but that when asked if they preferred online or written quizzes, 76% of students responded online. It was also found that 72% of students, when given the opportunity, attempted an online quiz more than once and "significantly improved their grades" in the quiz.

The findings of the above study are particularly relevant to the creation of our learning tool. Firstly, they support the idea of the tool being developed for online use. Secondly, it is clear that when quizzes are available for more than one attempt students will make the most of this and improve their performance. Therefore, making our tool available online to students and for more than one attempt will be utilised.

2.3.2 Investigation into Existing University Quiz Tools

The online quiz and test tools currently recommended by the university on their 'Tests and Quizzes' page are Blackboard Tests and Questionmark Perception [27].

Blackboard Tests [20] are currently very commonly used within the university as the main university virtual learning environment is BlackBoard Learn. Questionmark Perception [31] is also used to deliver formative and summative tests to students. However, due to the specific functionality of the SDM learning tool, neither software will be appropriate. The tool design involves navigating through multiple questions and for each question navigating through multiple answers, then, for each answer, a list of feedback statements is shown that the user must select the correct applicable statements from. This complex and unusual functionality cannot currently be easily implemented on either tool.

2.4 Chosen Technologies

2.4.1 General Appraisal

The tool is to be implemented as a static website. The website format was chosen firstly due to the amount of information required to be displayed on the screen - the previous lab-assessment question, answer and list of possible feedback statements would not fit on a non-scrollable mobile phone screen so, for example, a mobile app would not be a good choice. Secondly, it was chosen due to the ease of access - students do not have to download any particular software to access a website but only require a device (ideally

larger than a phone) that has a browser and is connected to the internet. A static website was chosen as this means the implementation can be done faster because there is only a front end to set up as static websites do not use a back end.

2.4.2 HTML and Bootstrap

As the standard markup language for the creation of web pages [40], HTML was used to create the front end of the tool. Bootstrap, an open-source framework (which is also free of charge) used for responsive front-end development [45], was used in conjunction with HTML for the layout and styling of the pages. This means the creation of the designed user interface should be easier and consequently faster.

2.4.3 Javascript

Chosen as it is not only particularly beginner-friendly, Javascript is also the "world's most popular programming language" [41]. Therefore, it is very well documented and there are an extensive number of resources available to assist web development in JavaScript making it an ideal option for the creation of the front end.

2.4.4 W3Schools Hosting

W3Schools is an online resource offering tutorials in a multitude of coding languages and describes itself as "the world's largest web developer site" [42] also offering 'Spaces' - platforms to build and host websites [39]. As a well-known and documented tool (specialising in beginners and tutorials) this seemed a favourable option for a hosting platform for the tool.

2.5 Evaluation Techniques

The first evaluation technique to be utilised will be a focus group. A focus group is when data is gathered through the interactions of a small group of people discussing a provided topic [16]. After the creation of the low-fidelity prototype, its adequacy needs to be evaluated by students who have previously taken SDM. A focus group is a particularly effective way to do this as they are "particularly useful for exploring people's knowledge and experiences" [18]. This is vital for this part of the process as the group will be made of prior course students and their key utility is their experience of the course.

The next evaluation technique to be used is questionnaires. They will be used to gather feedback on student experiences of the high-fidelity implementation of the tool. A questionnaire is a set of questions designed to ascertain participants' "attitudes, experiences, or opinions" [16]. This is a useful form of evaluation technique in terms of this project as it can be done quickly (through the use of a smaller number of questions with only multiple choice questions being mandatory) and online. This means that it can be done directly after the student has used the tool and so their experience will still be fresh in their mind meaning the data gathered should be very accurate.

The previously mentioned multiple-choice questions in the questionnaire will use a Likert scale. This means that statements about student experiences of the tool will be offered to participants and they will select the option from a scale that indicates best how they feel about it. The Likert scale used in this study will offer the following options - 'Strongly Disagree', 'Disagree', 'Neutral', 'Agree', and 'Strongly Agree'. This scale of answers is "designed to measure people's attitudes, opinions, or perceptions." [17]

Another evaluation technique considered for the high-fidelity prototype was the comparison of student results from last year's lab assessment and student results from this year's lab assessment. However, due to the university's employment of the Common Marking Scheme [38], marks should fit a similar distribution each year - regardless of tools/methods used. Therefore, even if the tool did improve student performance significantly compared to previous years, the course organiser would have to anticipate this and increase the lab assessment difficulty so the marks would still be in accordance with the Common Marking Scheme. Therefore, a direct comparison of marks would not be an appropriate method of evaluation.

A further evaluation technique considered was the use of a control group - using only the currently available methods of revision - and a treatment group - allowed access to the currently available materials as well as the created revision tool - which was the same method used by Rushton in their study of learning from errors [32]. This method, however, was discarded after a discussion with the project supervisor, due to ethical concerns. Considering all of the background research that has been conducted, it suggests the revision tool should be advantageous to students' performance meaning a likely improved result in the lab assessment. Therefore, not opening this opportunity to all students on the course would be unfair and unethical.

2.6 Design Approach

When creating the learning tool we will follow a design process inspired by that described in Bruce Hanington and Bella Martin's Universal Methods of Design [23]. The process is shown in Figure 2.1.

Figure 2.1: Design approach

'Scoping' and 'Analysis' has been done through the background research conducted in this chapter. 'Design & Concept Generation' will be done through the low-fidelity prototype design stage with 'Prototyping & Evaluation' being done through the creation of a low-fidelity prototype and a high-fidelity prototype of the tool. Finally 'Implement & Launch', although having taken place to some extent in the high-fidelity prototype evaluation, will be done through the handing over of the implemented tool to the project supervisor along with a list of suggested future developments.

Chapter 3

Low-Fidelity Prototype Design and Evaluation

3.1 Design and Generation

The first stage of the tool creation process is the design and generation of the low-fidelity prototype. This is a mockup of the tool's user interface. The purpose of the low-fidelity prototype is to gain feedback from both the project supervisor and last year's SDM students to improve the interface design. This chapter will therefore conclude with a valuable blueprint for the appearance and layout of the tool. The key screens of the initial prototype can be seen in Figures 3.1 and 3.2 and the full collection of screens can be found in Appendix B.

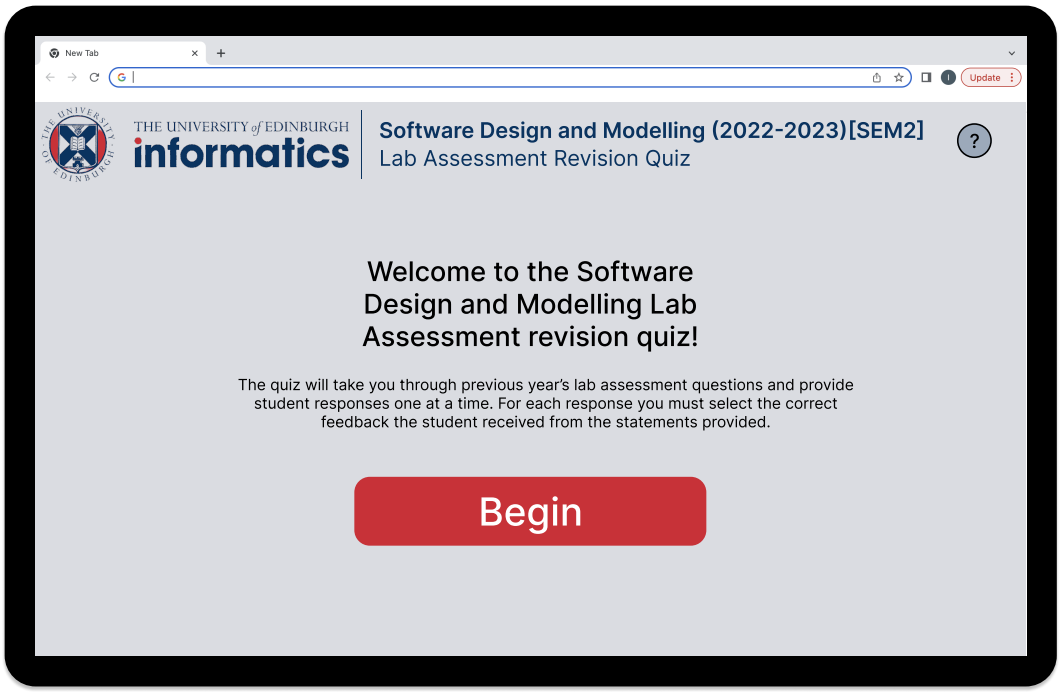


Figure 3.1: Low-Fidelity Prototype Start Screen

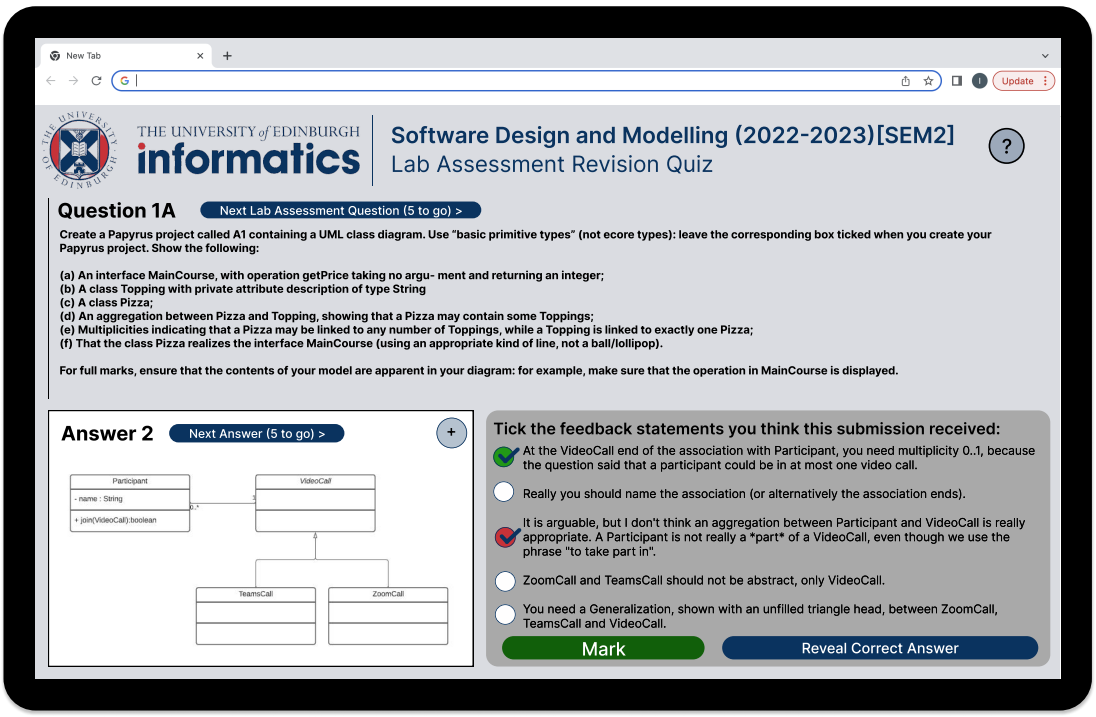


Figure 3.2: Low-Fidelity Prototype Marked Selected Statements Question Screen

3.1.1 Platform

Figma was chosen as the platform for the creation of the low-fidelity prototype. The "2022 Design Tools Survey" by UX Tools, which surveyed individuals in the software design industry, found that when asked what they used as their primary user interface (UI) basic prototyping tool, Figma not only receive the most votes but over 10 times as many votes as the next most popular tool (Adobe XD) [28]. This displays its huge popularity and influence on the industry [7] [19] since its launch in September of 2016 [9] and its ideal functionality for basic UI prototyping. In addition to this, I had prior experience working with Figma, making low-fidelity prototype creation a more efficient process. Finally, initial use of the tool is also free.

3.1.2 Nielsen's 10 Heuristics

Given that the low-fidelity prototype's main goal is to provide a preliminary design for the user interface of the tool, the human factor is the key consideration. As the interface will be used by non-expert (in this sense not involved with the design or creation of the tool) users it is important to consider their requirements and abilities throughout the design process. This will be done using Nielsen's 10 heuristics [25], a list which consists of 10 key principles to recognise when designing user interfaces. They are, and will be considered, as follows:

1. **"Visibility of System Status"** This is taken into consideration through the use of titles displaying what question number the user is currently on, having the number of questions and answers the user still has to go on the next buttons, and the colours of the checkboxes after marking so the user understands the correctness

of their answer.

2. **"Match Between System and the Real World"** The checkbox style used for feedback statements is reminiscent of that used on physical paper forms making it intuitive to the user how to select feedback statements. The red and green colours used for incorrect and correct answers are also commonly used in real life (e.g. red on a traffic light means stop/danger and green means safe to proceed).
3. **"User Control and Freedom"** Having next (answer and question) buttons available for the user means they feel in control of the tool and have the freedom to move through questions and answers as they please.
4. **"Consistency and Standards"** To create a sense of unity throughout the tool the top header remains constant on every screen. There is also a limited colour palette used so the user is not overwhelmed. Finally, the format of buttons also remains constant - oval shapes, solid colours, and arrows on buttons that move the user to the next question or answer.
5. **"Error Prevention"** To attempt to prevent users from making technical errors whilst using the tool there is a help button in the top right-hand corner of every screen. This takes the user to a help screen displaying how to use the tool and so allows the user to refresh their knowledge of how to operate the tool whenever they need it.
6. **"Recognition Rather than Recall"** Although the help button is available at all times for the user, to limit their need for it all question pages will follow the same layout. This means that users will stop having to read button captions and titles as it will become intuitive for them where everything is.
7. **"Flexibility and Efficiency of Use"** To make the user experience easier and faster the order of the feedback statements will not change between answers for the same question. Therefore as the user progresses through different student answers for a particular question they will not have to keep rereading feedback statements once they become familiar with their order.
8. **"Aesthetic and Minimalist Design"** Although the question screen of the tool hosts a large amount of information, this is split into 3 blocks - question, answer, and feedback statements - to help the user easily identify each component. The answer image is also restricted to a constant size for every answer.
9. **"Help Users Recognize, Diagnose, and Recover from Errors"** As a teaching quiz, the user will likely make errors when selecting feedback statements. To allow them to recover from this, checkboxes for wrong-selected statements turn red so the user can recognize and diagnose their error. Then they can deselect and re-select statements and re-mark their answer to allow them to recover from the error.
10. **"Help and Documentation"** As previously mentioned, there is a help button consistently available on all of the tool's screens where the user can view how to use the tool. There is also the option to view an enlarged version of the answer image.

3.1.3 Content

The idea of the tool is that students view a series of questions taken from the previous year's mid-term lab assessment. For each question, the students can go through a series of student answers that were given by the previous year's SDM students to that question. The current student must attempt to select the correct feedback statements from those displayed that each answer received. Therefore, one of the biggest issues facing the prototype came from the quantity of information required to fit on the questions screen:

- **Question** As they express detailed scenarios for students to create UML diagrams from, the mid-term lab assessment questions are usually a few paragraphs long. See Appendix A.1 for the previous year's mid-term lab assessment questions.
- **Student Answer** Various UML diagrams are tested throughout the lab assessment and therefore student answers for different questions will be different sizes. See Appendix A.2 for an example of a student's answers to last year's mid-term lab assessment.
- **Feedback Statements** Given the relatively high number of students on the SDM course (89 in 2022/23) and the correspondingly high number of answers submitted, the number of feedback statements is extensive (some questions have nearly 40 feedback statements available and all questions have a different number of statements). See Appendix A.3 for an excerpt of the raw feedback statements.

Measures were taken to combat the issue of the quantity of information required to fit on the page. Firstly, each of the 3 components above was given its own set space on the page so a consistent layout could be maintained between questions, answers, and feedback statements. In terms of the answer images, the container for them will not change size and although this means that some images may be stretched/constrained, this was mitigated with the zoom button - allowing for an enlarged version of the original image to be shown. To ensure that the feedback statements would all fit within their container, the container was made to be scrollable. This meant that any number of statements could be provided with questions.

3.1.4 Supervisor Feedback

After the creation of the low-fidelity prototype, a discussion was held with the project supervisor to ensure they were happy with the design. This discussion yielded the following pieces of feedback which were implemented:

- Initially the low-fidelity prototype design considered the marks each question was worth and how many marks each answer received. However, after conferring with the supervisor all mentions of marks were removed from the planned design as it was concluded that the involvement of marks and scores within such tools drew students' attention too much away from the main content.
- The initial design also indicated the correctness of selected feedback statements about the current answer by changing the colour of the checkbox tick. However, the supervisor noted that this may not be obvious enough and that they would

prefer to see the checkboxes themselves change colour to create more of an impact.

3.2 Focus Group Evaluation

To evaluate the suitability of the proposed user interface design represented by the low-fidelity prototype, a focus group with past SDM students was held. The focus group also investigated student opinions on the core tool concept.

3.2.1 Aims

The aims of this focus group were:

1. Find out what difficulties the students faced in their mid-term lab assessment and if this tool would have helped with these.
2. Find out the students' opinions of revision techniques and materials they used in their preparation for the lab assessment and how the proposed revision tool relates to these.
3. Find out if there were any improvements/additions students would suggest to improve the usability of the tool and how these may be incorporated into the tool.
4. Find out what aspects of the user interface design the students liked.

3.2.2 Participants

The biggest challenge faced when hosting the focus group was sourcing participants. Due to delays in receiving ethics approval and illness, the focus group was held later than initially planned. The focus group was held at the beginning of the period between the end of semester 1 and the beginning of semester 1 exams. For many students this is a time of revision and final coursework submissions so it was thought that interest may be low, however, to avoid further delays to the high-fidelity prototype's implementation, release, and evaluation, the focus group could not be delayed any further.

To gather focus group participants, the project supervisor sent an email to all SDM students from the previous year asking for volunteers to participate. Unfortunately, this yielded no responses. As previously detailed this was likely due to students having heavy workloads as well as the pool of students emailed being fairly small - as the course is open to third and fourth-year students it is likely a significant portion of the students who had previously taken SDM had graduated.

Fortuitously, I had taken SDM the previous year and knew of some current fourth-year students who had also taken the course and 3 of these students agreed to participate. However, in the days before the focus group 1 of the number dropped out due to personal reasons. Although 2 participants is a particularly small number for a focus group, and has more resemblance to a multi-participant unstructured interview, the evaluation was still able to be conducted and feedback gathered.

3.2.3 Methodology

1. **Ethics Approval** As previously mentioned, ethics approval had to be granted before hosting the focus group. This consisted of generating a Participant Information Sheet (see Appendix C.1) and Consent Form (see Appendix C.2) for the focus group participants and submitting them to the Informatics Ethics Approval Panel.
2. **Gathering Participants** See section 3.2.2 for more information on this stage.
3. **Preparation to Host Focus Group** The location of the focus group was a university group study space which was booked in advance after agreeing on a date with the study participants. Multiple copies of the participant information sheets and consent forms were printed to give to participants. Although focus groups are led by the participants' flow of conversation, an agenda (see Appendix C.3) was also created in advance to provide direction and ensure all relevant topics were covered and aims met.
4. **Hosting Focus Group** On the day of the focus group the room was set up with participant information sheets and consent forms at each of the participants' seats, the low-fidelity prototype on the big screen, and an audio recorder ready to begin recording. After the participants had arrived and read the information sheet and signed the consent form, the focus group began following the format of the agenda (see Appendix C.3). This consisted of firstly giving an overview of the focus group format and purpose, then discussing the mid-term lab assessment and revision, before explaining and discussing the low-fidelity prototype and tool.
5. **Transcribing Audio Recording** Following the focus group meeting the audio recording was transcribed. This transcription was then analysed and key feedback areas were drawn from the participants' comments.

3.2.4 Data Analysis and Results

Although the data was more limited than would have been desirable, having only come from 2 participants, the feedback still provided enough insight into student opinion to evaluate the initial focus group aims. Key comments from students which can be used to do this are listed below:

"Participant 1: ...if you made one small mistake you could lose about half of the marks for that question [Participant 2 voices agreement]",

"Participant 1: It was the forgetting the little things.",

"Participant 2: Accuracy was quite hard"

This feedback helps achieve **aim 1**. It was reiterated by both participants that one of the aspects they struggled most with was the level of detail and accuracy required for the UML diagrams in the assessment. The proposed tool would be helpful here as its core purpose is to help students spot errors in UML diagrams which subsequently should help students to look further into the detail of UML diagrams and so improve accuracy in their own diagrams. Participants also stated about the tool (Participant 1) *"that would*

have been useful for nit-picking" and (Participant 2) *"I now know that based on the accuracy that it would have been useful"*, agreeing that the tool would be helpful for this aspect.

"Participant 1: I used the videos that she provided, I thought they were quite useful [Participant 2 agrees].",

"Participant 2: I didn't like the labs because as they were self-driven it was harder to learn – you were just doing it yourself. The problem with the labs was, and maybe that's what went back into my mid-term, that if I made mistakes in the labs I had no clue I made mistakes in the labs because you did it yourself in your own time – there wasn't anyone to mediate it or anything like that or ask for help."

This feedback helps achieve **aim 2**. Discussing revision for their mid-term lab assessment the participants mentioned that they used the previous year's lab assessment questions with the solution videos provided by the supervisor and completed the labs provided in the early weeks of the course. They concurred that being provided with solutions for the previous year's lab assessment was very helpful and that not being provided with solutions for the labs caused difficulties (although in non-pandemic years when the lab was held in person they would have had more help/solutions). Regardless, both points imply that the students liked seeing answers to practice questions which supports the main concept of the tool - providing a selection of answers to previous lab assessment questions for student evaluation.

The next student comments achieve **aim 3**:

"Participant 2: Is it aimed for you just to go through it once or can you go back and forward through it?

One feature brought up by a participant was the absence of back buttons for questions and answers. This was noted as an aspect to add to the tool as it would also improve Neilsen's third usability heuristic - User Control and Freedom.

"Participant 2: ...it would be better to have that bigger."

Discussing the student answer image, participants agreed that it would be good to be able to view a bigger version. Although this was already planned functionality in the design (zoom button) it was noted that this should be a priority in implementation.

"Participant 2: Maybe you could zoom into the question like you can zoom into the answer?"

It was also mentioned that to reduce clutter on the question screen the question itself could be made smaller and have a zoom button like the one planned for the answer image. However, allowing the user to be able to open multiple enlarged popups of different parts of the screen added an extra layer of complexity to the tool's already cluttered question screen and so was not added.

"Participant 2: Would you be able to give like a sample solution because I guess it's like feedback but it's also good to have a perfect answer [Participant 1 agrees], although I know informatics tends to avoid giving out perfect answers. There's going

through enough answers but then being able to view the perfect solution because you only get feedback on what that answer is."

The participants concurred that they would like the option to view a perfect/model answer after completing a question. This feature was not added as the core purpose of the tool is to help students spot errors in UML diagrams rather than practice lab assessment-style questions. In addition, for most questions to be used in the tool there was one student answer that had received only positive feedback (and so was essentially a model answer).

The following student comments achieve **aim 4**:

"Participant 2: This is like a good tool, like what any informatics student wants at the moment like able to see past answers and where they got it right and where they got it wrong, because I know sometimes the marking scheme isn't as helpful or you don't get one."

"Participant 2: No, I think it's typical informatics – not like crazy. I would expect this to be a university resource tool."

"Participant 1: Yeah I can see that being quite useful. [Participant 2 agrees]"

"Participant 1: I think it's good you have the option of trying a different question [Feature that allows skipping to the next question] if you're already comfortable with the current type of question or you can choose a different student answer if you want to practice a bit more on that specific type of question. So I like how you've got the option to kind of do what you want."

The students concluded that in addition to the main concept of the tool they liked several other aspects of the design and functionality such as the general aesthetic and style, and the ability to move past a question even if the user had not completed all answers.

3.2.5 Significance

The focus group was conducted to gather the opinions of previous SDM students about their experience of the course and to ascertain whether the proposed tool could have improved this, as well as to gauge their opinion of the proposed lab tool design.

In terms of their own experience, students felt that one of the aspects they struggled most with in terms of the mid-term lab assessment was the detail and accuracy involved in UML diagrams. It was felt a tool specifically designed to target spotting errors in these diagrams would have been helpful to them and that the proposed interface would be suitable for this.

In terms of the students' opinions of the low-fidelity prototype, the following key pieces of the feedback participants offered were acted upon:

1. Back buttons to aid user navigation between questions and answers.
2. Higher priority for the zoom button for the student answer image.
3. Ensuring that the question is large enough to be easily read on the screen.

Chapter 4

High-Fidelity Prototype Design and Implementation

4.1 Data Gathering, Cleaning and Inclusion

The data to be used in the tool comes from the previous year's SDM mid-term lab assessment questions, answers, and feedback. The student answers had been anonymised by the project supervisor before being passed on.

Whilst the original plan for the project was to implement a feature to allow the supervisor to drag and drop files into the tool and have them automatically upload as questions, this was not implemented due to time constraints - several delays cut the implementation time short. As I had very little prior experience working with HTML or JavaScript, I ended up putting my time and effort into the development of the core of the website (functioning "Mark Answer", "Next Answer" buttons etc.) and so was unable to implement an automatic upload feature in the time left. The data was therefore stored as a constant in the JavaScript file for the website.

Data was organised, cleaned, and added to the tool as follows:

4.1.1 Questions

For the past few years the mid-term lab assessment paper has followed the same structure:

- **Part A** Worth 50% of the mark
- **Part B** Worth 30% of the mark
- **Part C** Worth 20% of the mark and is only marked if the student has achieved at least 70% in parts A and B.

The 2021/22 Lab Assessment paper can be found in Appendix A.1 Both Parts A and B required the students to submit their answers as PDF/PNG files. However, Part C could be submitted as 1 or more of 5 different files. This meant that Part C would require a significant amount of cleaning to standardise every student answer to 1 file type which

could be passed to the tool. In addition, Part C focuses on the analysis of UML tools rather than UML models and diagrams themselves. Both of these points meant that Part C was removed from the tool and only Part A and B, and their sub-parts, were focused on.

4.1.2 Answers

Standardising the student answers provided also posed a challenge. The answers, from students who had consented to the use of their solutions and feedback in the tool, were sent on by the supervisor in the form of one folder per student and each student folder contained all answer files submitted by that student and a 'feedback.txt' file of all the feedback statements each student received. The issue lay in the organisation of each student folder - some students' answers were in a sub-folder which varied in name between students. To standardise the file layout for it to be appropriate for use in the tool, in each student file the answer files were added to a sub-folder named 'done'. Standardising file layout and naming was an important part of the tool's conception so that rather than, during the addition of data into the tool, having to check the file path of each answer image individually and insert it, each file path was the same with only the student filename needing to be changed.

4.1.3 Feedback

The feedback was provided as a document containing every feedback statement that had been used to mark a student's answer in SDM that year and so it also posed a challenge to standardise. The first issue came from the lack of identification of each statement. Therefore, storing the files in the format in Listing 4.1 would require huge amounts of repetition - i.e. feedback statement ID numbers wouldn't exist and so there would be a full feedback statement in its place. It would then also require the exact matching of the same feedback statements for different answers to each other (so no duplicates were presented on the question interface in the feedback statement box) and so even the difference of a full stop between statements would break this functionality. In addition, there was also a huge quantity of feedback statements present, for example, Question A2 alone had 40 statements. Therefore, the following procedure to clean the feedback statements was carried out:

1. The statements were reduced to only those applicable to the student answers given to be used in the tool.
2. After discussions with the project supervisor further statements that were too similar to each other were combined. For example the statements:
    - "*Show the object creation as usual with a <<create>> message to a new lifeline, that starts at the point of creation.*",
    - "*Strictly speaking the create message wants a <<create>> label or similar and is given a -> head - see solution video.*" and
    - "*Label the creation message <<create>> - see solution video.*"

These were all replaced with the statement "*Object creation not shown correctly*".

3. The student answers and their applicable feedback were then reviewed for inconsistencies. For example, "*Really you should name the association (or alternatively the association ends).*" was applied to some student answers with associations not labelled, but not others. Therefore, it had to be applied to these answers as well.
4. The collated feedback statements for each question were then numbered and each student answer matched with their feedback statements' IDs as in Listing 4.1.

4.1.4 Data Incorporation

```
const questions = [
    {
        number: 'Question A1',
        question: 'In LucidChart draw a UML class diagram showing: \
           n(a) a class ... scheduled calls).\n\n',
        answers: [
            { image: '/2021/StudentA/done/A1.JPG', correct: [4, 9]
               },
            { image: '/2021/StudentB/done/A1.JPG', correct: [5, 4,
               9] },
            ...
            { image: '/2021/StudentR/done/A1.JPG', correct: [4, 9] }
        ],
        checkOptions: [
            { id: '1', text: ``Perfect!"},
            ...
            { id: '9', text: ``Really you should name the
               association (or alternatively the association ends)."
               }
        ]
    },
    ...
]
```

Listing 4.1: Excerpt of Constant Structure used to Store Question, Answer and Feedback Data

The data was incorporated into the tool through the structure in Listing 4.1 where an excerpt is shown. The full data structure from the tool with the final cleaned data can be found in Appendix D.

4.2 Tool Screens

This section discusses each screen of the high-fidelity prototype. This is to give a general overview of the tool's functionality and flow. Therefore, smaller images have been included, however, enlarged versions of each screen are included in Appendix E.

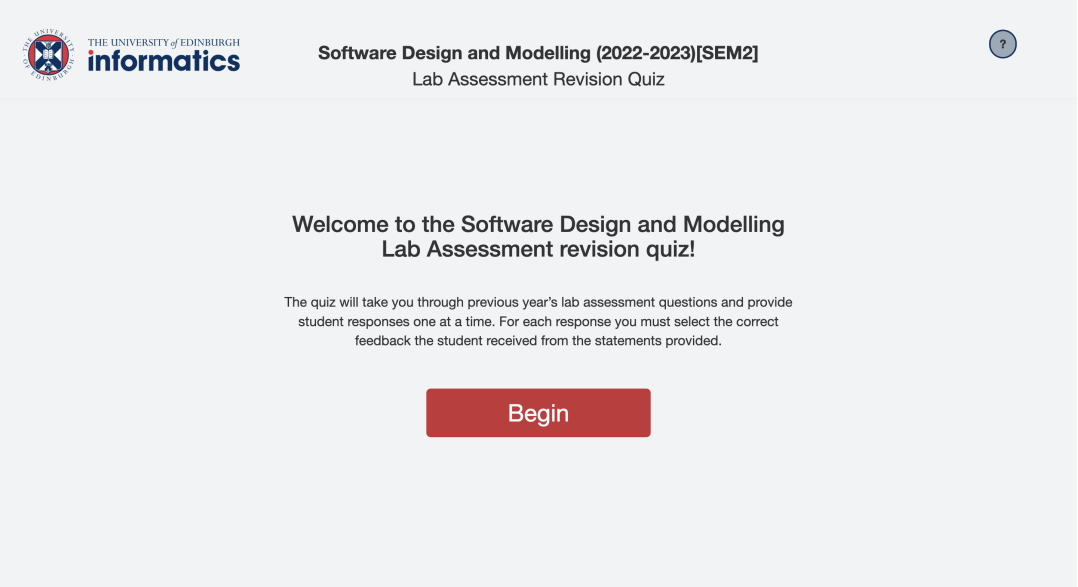


Figure 4.1: High-Fidelity Prototype Start Screen

4.2.1 Starting Screen

When students access the tool's URL the start screen shown in Figure 4.1 is the initial screen to appear. It is designed to give them a brief overview of the tool before beginning the quiz. If students would like more information on how to use the tool they can click the help button at the top right of the screen.

4.2.2 Help Screen

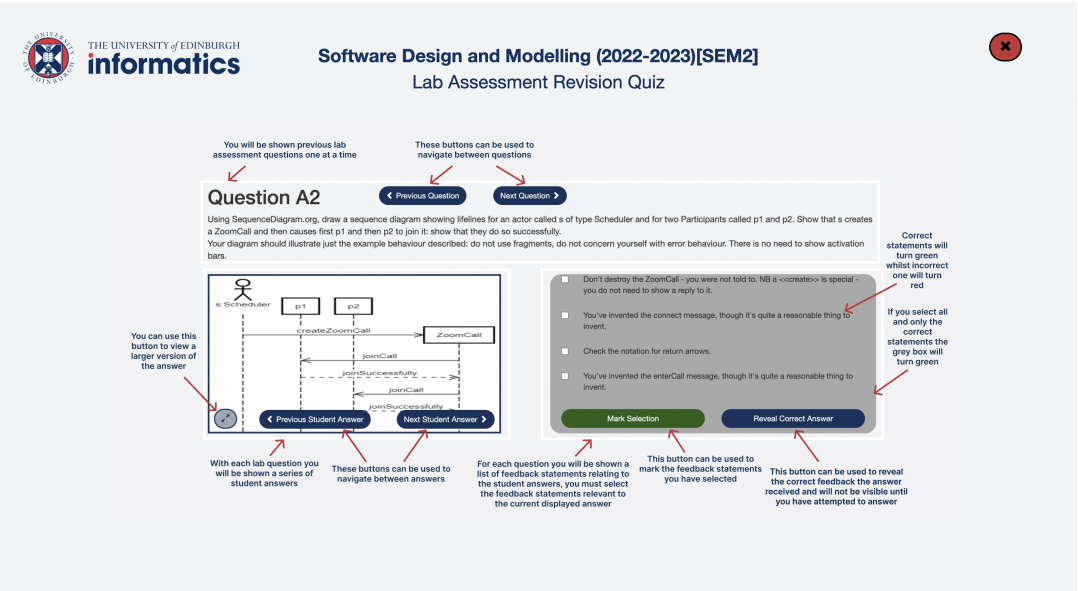


Figure 4.2: High-Fidelity Prototype Help Screen

If students select the help button, located at the top right-hand corner of every screen in the tool, they will be presented with the screen in Figure 4.2. The screen consists of an image of the main tool interface annotated with descriptions and instructions on how to use each feature. By pressing the red 'X' button in the top right-hand corner the students will be taken back to the last screen they were on before using the help button.

4.2.3 Question Screen

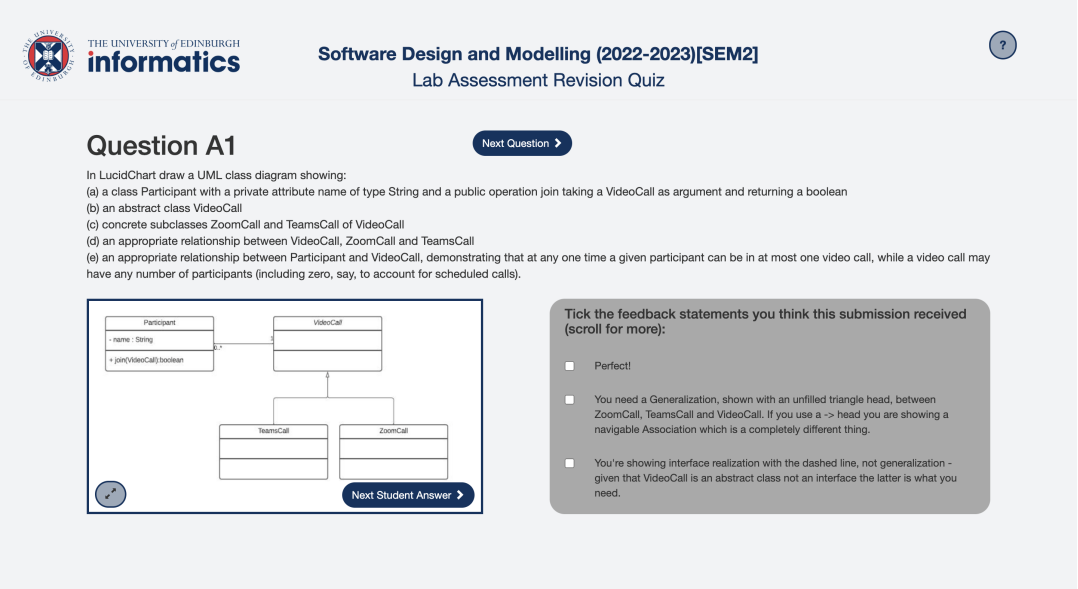


Figure 4.3: High-Fidelity Prototype Question Screen

Once students select the 'Begin' button on the start screen they will be taken to the questions screen, one of which is shown in Figure 4.3. They will be shown a question, a student answer, and a list of potentially applicable feedback statements. The student then has multiple options:

- They can, as intended for the majority of answers, select feedback statements they think apply to the current student answer and then select the 'Mark Selection' button to review these and find out whether they are correct. The result of pressing this button is shown in Figure 4.4 (red statements are those incorrectly selected - not applicable to the student answer - and green statements are correctly selected - applicable to the student answer).

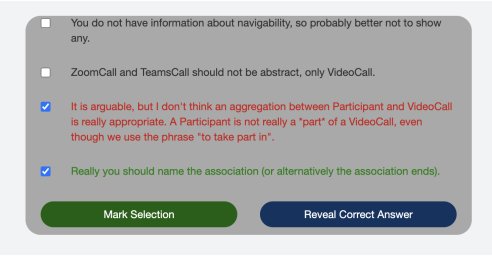
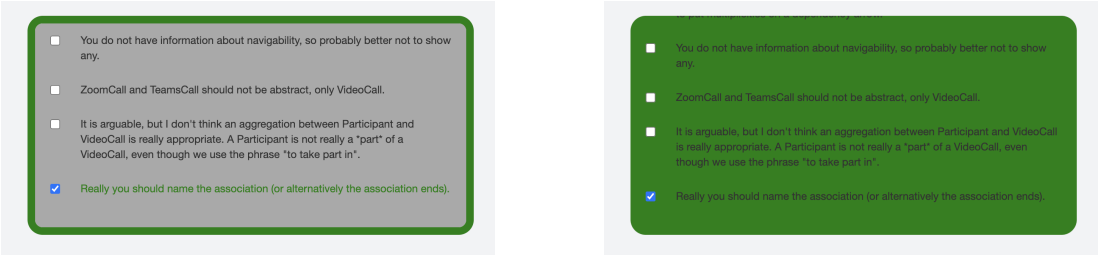


Figure 4.4: Feedback Box After Marking Selected Statements



(a) Chosen and Marked (b) Revealed

Figure 4.5: Feedback Box Showing Correct Statements

Post-marking, students will have the option to reveal the correct answer (this button only appears after the student has attempted to select feedback statements at least once) resulting in the feedback box appearance in Figure 4.5a, or try again until they reach the correct answer - selecting all correct feedback statements and then marking them which results in the feedback box appearance in Figure 4.5b.

- If they are finished with the current answer they can move to a different student answer for the current question using the 'Next Student Answer' button (unless it is the final question where they can select the 'Finish' button).
- If they have already reviewed multiple student answers for a question and don't want to do more/have no more to do they can move to the next question using the 'Next Question' button.
- They can enlarge the current student answer image, as in Figure 4.6, using the button at the bottom left corner of the student answer image, if they would like to see it in more detail.

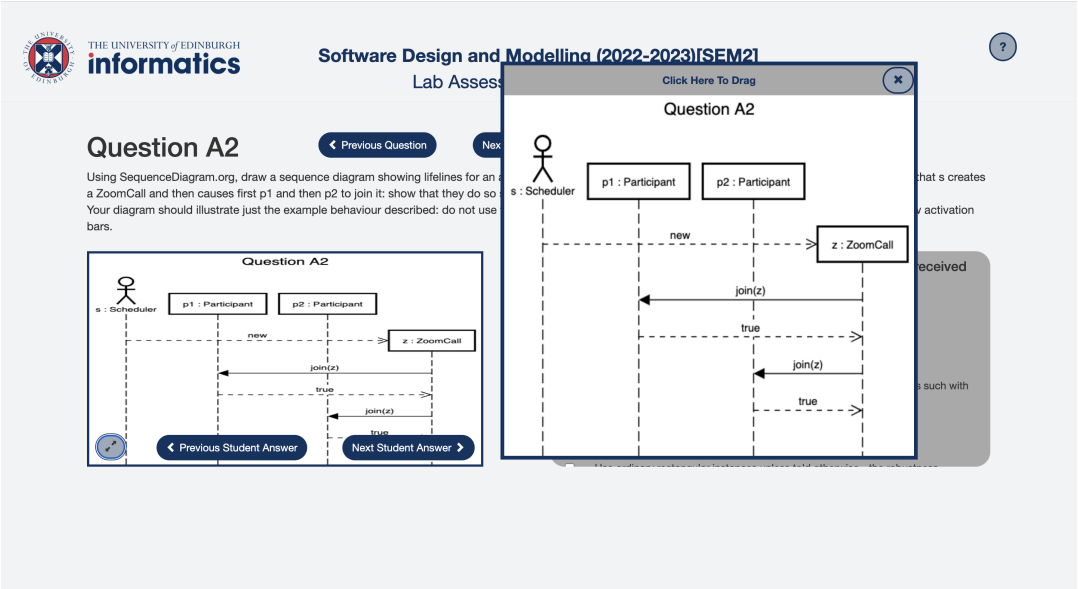


Figure 4.6: Feedback Box After Marking Selected Statements

4.2.4 Completion Screen

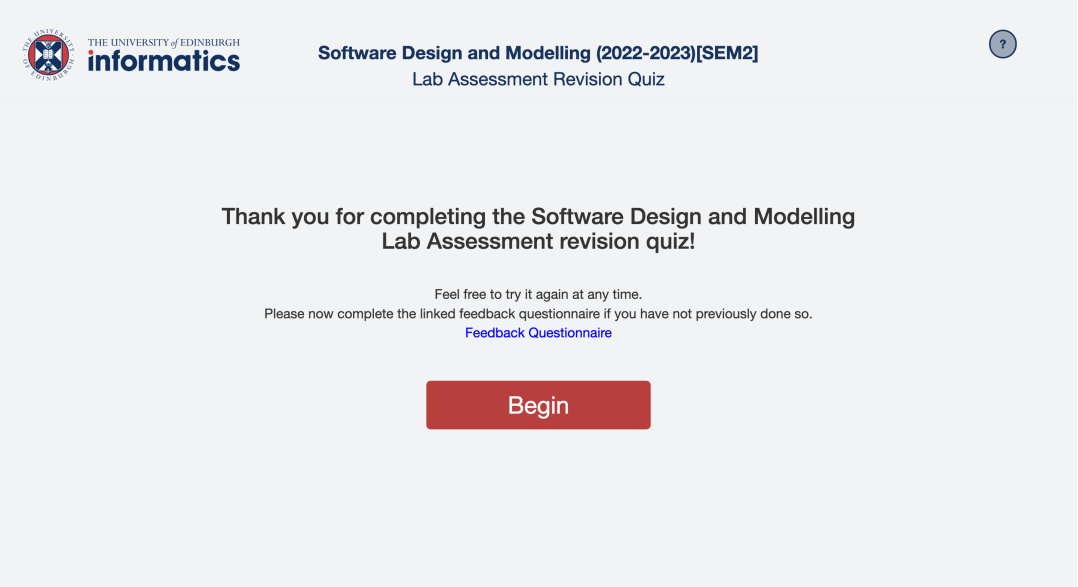


Figure 4.7: High-Fidelity Prototype Completion Screen

Once students navigate through all of the questions they can click the 'Finish' button. This will take them to the screen in Figure 4.7 where they can restart the tool or complete a feedback questionnaire for the evaluation of the tool (this is discussed further in Chapter 5).

4.3 Implementation

4.3.1 Front End

With very little prior experience in HTML and JavaScript, I began implementation by following an online tutorial on how to create a quiz website [36]. Subsequently, I used HTML with Bootstrap to create a website following the same layout as the low-fidelity prototype design. Next, I implemented the quiz functionality and, following that, I integrated the data into the design.

4.3.2 Hosting - GitHub Pages

After realising that the initial chosen hosting platform - W3Schools - only allowed for a certain number of files to be used in website creation, the platform was changed to GitHub Pages [11]. This was chosen as the new hosting platform as it allows unlimited files (up to a combined limit of 10GB) to be used and one website to be hosted for free [10]. GitHub Pages was used by first creating a GitHub repository and then adding to it all the files currently stored locally. After being uploaded and all changes pushed, the website could be accessed using the given GitHub URL.

4.3.3 Challenges and Implemented Solutions

- **Issue** The checkboxes used for students to select a feedback statement on the questions page changed colour when selected. It, therefore, added an extra level of complexity, given the checkboxes even when resized were not very large and mostly taken up with the selection tick, that there was another colour change to them once statements were marked.

  Solution The idea was altered so that the selected statements' text itself would change colour, based on correctness, when marked as in Figure 4.4. This was done by creating 2 classes in the style sheet of the questions screen HTML, as in Listing 4.2, and adding/removing them from statements depending on their correctness, as in Listing 4.3.

```
1    .correctAnswer {
2        color: green;
3    }
4    .incorrectAnswer {
5        color: rgb(206, 16, 16);
6    }
```

Listing 4.2: Classes to Colour Feedback Statements

```
1    if (correctAnswers.includes(i)) {
2        document.getElementById('label'+i).classList.add('
             correctAnswer')
3    } else {
4        document.getElementById('label'+i).classList.add('
             incorrectAnswer')
5        correctAnswersOnly = false
6    }
```

Listing 4.3: JavaScript Showing Selected Feedback Statement Marking Process

- **Issue** Another issue was the presence and absence of buttons on the questions page. For example, the previous and next buttons are needed for every question/answer except the first one and the last one, and the reveal button should only be present after the student has attempted to select the feedback for a particular question at least once and then should disappear when correct feedback is selected and marked or revealed. The complexity of this functionality and so regular changes in button visibility meant that some instances of buttons appearing/disappearing were missed.

  Solution To combat this, thorough testing of the high-fidelity prototype had to be conducted. This was done through a variation of Edge Case Testing. A variety of situations that may occur for students when using the tool were listed (including as many as possible unlikely ones) and subsequently tested. A few examples of these scenarios follow:

  - The student would like to move from the final question/answer to the first question/answer.
  - The student completes the answers/questions starting from the last one and moving to the first.

  - The student selects statements and reveals the correct statements for the same question 5 times in a row.

  This found multiple incorrect instances of button visibility. For example, when navigating to the last student answer for a question and then back to the first answer again the 'Next Answer' button would disappear for good. Bugs such as these were noted and fixed.

- **Issue** Another challenge was the varying number of feedback statements for each question in the tool. This meant that checkboxes would have to be removed/added from the questions page between questions which - through deleting and creating checkboxes in JavaScript - would be a costly solution.

  Solution This was dealt with by having a number of checkboxes present in the HTML code on the questions page greater than the greatest number of feedback statements for any question. This meant that each question could use the number of checkboxes that they needed and hide the rest. This was an efficient solution for this initial implementation (given the time constraints), however, should be kept in mind for any future developments/addition of more data.

- **Issue** After researching how to host a website able to be accessed from any device (i.e. not just hosted locally) I decided to host the tool on W3Schools. However, after this decision was made it transpired (due to this fact not being explicitly stated by W3Schools) that a limit on the number of files for their free spaces is imposed and so (as many image files are required to be stored for all of the student answers) this meant it could not be used after all.

  Solution GitHub Pages was used to host the website instead. This allows for an unlimited number of files on their free plan and still provides the necessary functionality.

- **Issue** A particular challenge for the implementation was the time frame for the creation of the high-fidelity prototype. Initially, the project process was to be conducted as shown along the top of the timeline in Figure 4.8, however, due to a delay in response from the ethics panel, issues gathering student participants for the focus group, and illness, some of the key dates had to be revised to those shown below the timeline in Figure 4.8 in red. Whilst this meant certain aspects of this project could be worked on in the meantime such as the preparation of evaluation resources; learning how to use HTML, JavaScript and Bootstrap; data cleaning (which took longer than anticipated and required the revision of SDM materials and UML diagrams); and further research into hosting platforms, it meant the implementation time was significantly reduced. This meant that implementing all of the planned tool functionality was not possible (particularly as the hosting issues detailed above also added time to the implementation).

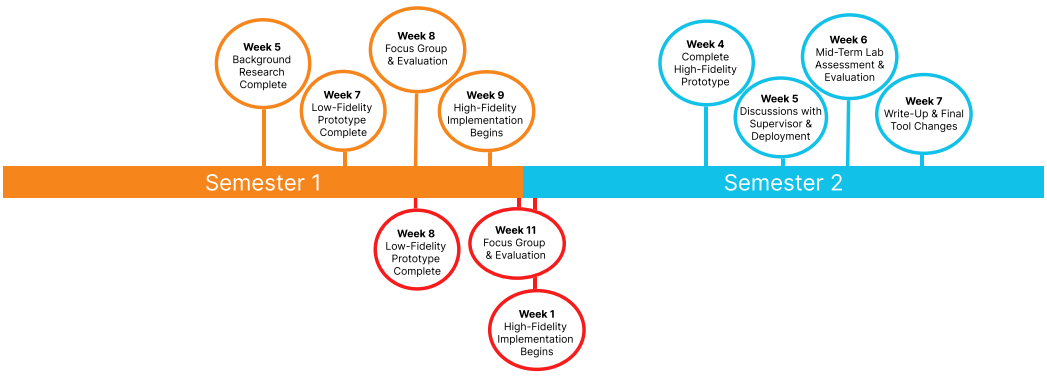


Figure 4.8: Project Timeline (Revised Dates are in Red)

Solution To resolve this, a list of the planned tool features was collated and ordered based on how essential each was to the tool implementation and what order was sensible (e.g. if the implementation of a feature required another feature to already exist). The tool features were then implemented in this order with the most essential features created first. Therefore, although some aspects of the tool were not able to be completed, these were limited to aspects of the tool not necessary for the main tool functionality planned to be provided for students and so the tool was still able to be deployed for evaluation and use of current SDM students. The prioritised list of features is as follows:

1. Existence of a question page for the tool which displays question, answer and feedback data.
2. Navigation between questions and answers (previous and next buttons).
3. Feedback statements can be selected and deselected.
4. Feedback statements can be marked.
5. The correct Feedback statements can be revealed.
6. An enlarged version of the student answer image is available.
7. The tool is hosted online.
8. There are start, final, and help pages for the tool. (This was the last feature able to be implemented in the revised timescale.)
9. New questions/answers/feedback can be uploaded to the tool automatically.
10. The number of questions/answers the student has left are displayed on the next buttons.
11. Students are offered feedback after their selection about key areas they are going wrong in.
12. An algorithm to show students easier questions/answers (based on the questions students were performing well in) first before getting progressively more challenging is implemented.

13. New questions/answers/feedback can be uploaded to the tool automatically.
14. Hints are offered to students (stating how many statements apply to the current answer - i.e. how many statements the student has to select).

4.3.4 Supervisor Feedback

After the initial high-fidelity prototype was complete (in time to allow a week to finalise changes and prepare for the user evaluation) the project supervisor was consulted. They gave feedback and suggestions regarding the tool's functionality.

Firstly, they requested that the enlarged student answer popup be movable with the question screen content still functional. This was because in the original implementation only the popup was accessible when it appeared - some of the question screen was visible behind the popup but not functional (see Listing 4.4 for initial implementation of modal popup using code from Bootstrap documentation [2]). This meant that no other aspect of the page was fully visible (as they were partially hidden behind the popup) and the feedback statement box was not scrollable when viewing the enlarged student answer. Therefore, the implementation of the enlarged student answer was altered so it was a draggable element that appeared in front of the main question screen but with no change in its functionality. Whilst I found this initially challenging (having never seen this implemented before), after some research a resource was found on W3Schools which provided code to make an element draggable in HTML and JavaScript [33] (see Listing 4.5 for adapted HTML). This code was used and adapted to make the enlarged student answer draggable.

```
1  <div class="modal fade" id="zoomModal" tabindex="-1" role="dialog"
       aria-labelledby="zoomModalLabel" aria-hidden="true">
2      <div class="modal-dialog modal-dialog-centered modal-lg" role="
           document">
3          <div class="modal-content">
4              <div class="modal-body">
5                  <img id="modalImage" src="/2021/StudentA/done/A1.JPG
                       " width="100%" height="100%">
6              </div>
7              <button class="btn zoomButton text-center" id="
                   zoomOutButton" data-dismiss="modal" aria-label="Close
                   "><span class="glyphicon glyphicon-resize-small"></
                   span></button>
8          </div>
9      </div>
10 </div>
```

Listing 4.4: Before Popup Draggable (Modal Used [2])

Another change discussed with the project supervisor was the visibility of buttons. The initial implementation of the High-Fidelity Prototype had the 'Next Question' and 'Next Answer' buttons only appear after the student had attempted to select the correct feedback statements for the current student answer. The idea behind this was to ensure students were attempting to review every answer, rather than just those they felt comfortable doing. However, the project supervisor noted that as some answers were

similar to others it meant students may begin to find the tool repetitive and, in addition, meaning that if students used the tool a second time they couldn't skip to answers that they hadn't previously attempted. Finally, the absence of navigation buttons also reduced 'User Control and Freedom' (Neilsen's third heuristic). Therefore, it was decided that the next and previous question/answer buttons would always be available to students.

```
<div id="mydiv" class="mydiv hide">
    <div id="mydivheader" class="mydivheader">
        <b>Click Here To Drag</b>
        <button class="btn zoomOutButton" id="zoomOutButton"><span
           class="glyphicon glyphicon-remove"></span></button>
    </div>
    <img id="modalImage" src="/2021/StudentA/done/A1.JPG" width="
       100%" height="100%">
</div>
```

Listing 4.5: After Popup Draggable (Draggable Div Used [33])

In week 3 of semester 2, close to the completion of the high-fidelity prototype's implementation, I met with my project supervisor as well as a different project supervisor (who had never seen my project before) to give a presentation of my project progress. This meant I could gather the opinions of an expert who knew the project well and that of an expert looking at it for the first time (similar to the way the ultimate users of the tool will be). Some feedback from this other project supervisor was that, as the tool was currently not resizable (did not adjust to different computer screen sizes) I should try to implement this. Through the use of Bootstrap 'fluid containers' and setting certain sizes as percentages rather than in pixels, this resizable functionality was achieved.

Chapter 5

High-Fidelity Prototype Evaluation

To evaluate the efficacy and suitability of the high-fidelity prototype, a link to a short questionnaire was added to the final screen. This meant that on completion of the tool students could provide feedback on their experience and this could be used to evaluate the high-fidelity prototype.

5.1 Aims

The aims of the questionnaire were:

1. Find out if students found the tool effective in their education and revision of UML diagrams in preparation for the SDM mid-term lab assessment.
2. Find out if students liked using the tool as a form of revision in preparation for the SDM mid-term lab assessment.
3. Find out if students found the tool usable and understandable.
4. Find out what students liked about the tool.
5. Find out what improvements students would suggest for the tool.

5.2 Software Design and Modelling Course Lab

In the semester in which the SDM course is taught, weekly labs are held to give students a chance to further their understanding of that week's materials whilst being able to ask the course tutors/supervisor questions. In previous years SDM was hosted in semester 1 in which there are 11 weeks and no reading week (a week of no classes between weeks 5 and 6). As the mid-term lab assessment is hosted in week 6, week 5 of semester 1 was made a 'reading week' (i.e. no new materials taught) for SDM students to revise. However, as this year SDM was hosted in semester 2 there was already a reading week in place for students to revise. This, therefore, left the week 5 lab without a topic and so it was used as an opportunity to present the tool to students before allowing them to have a chance to use it in the presence of myself and the project supervisor.

5.3 Participants

The participants for the evaluation were from the current pool of SDM students. Whilst only a portion of students attended the lab, the presentation explaining the tool and tool link were added to the course page so that every SDM student had access if they wanted. Given the course had 89 students that participated in the mid-term lab assessment this year it was expected that whilst some students using the tool may choose to avoid doing the questionnaire (e.g. to save time and spend longer revising), that there would likely still be some responses.

In the period between the release of the high-fidelity prototype of the tool (at the lab) and the mid-term lab assessment, the questionnaire received 15 responses. Whilst this is only 17% of the students on the course it still provided enough data for evaluation.

5.4 Methodology

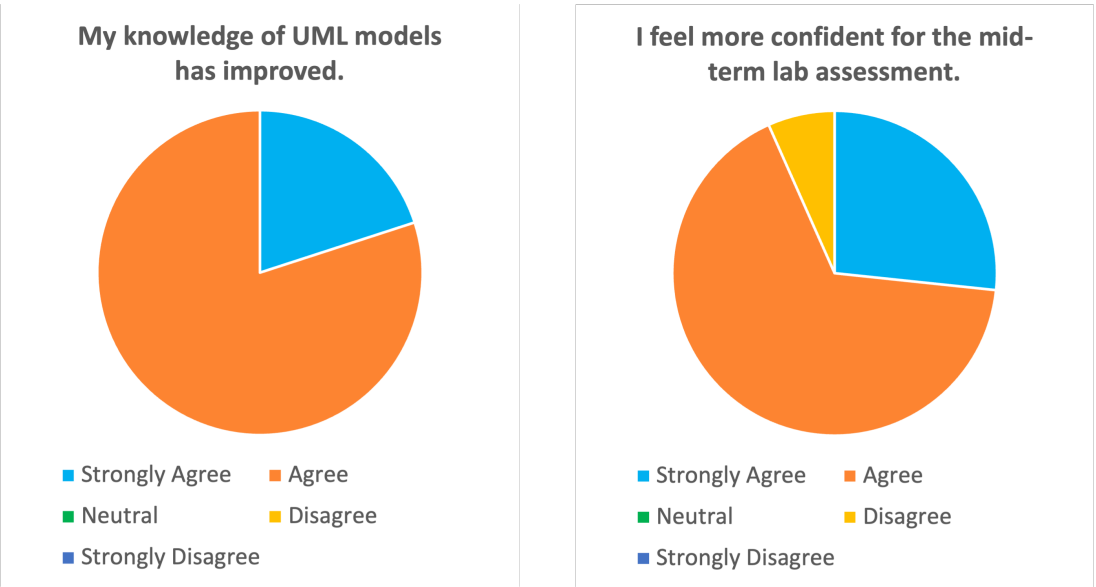
1. **Ethics Approval** The first stage of the evaluation was to gain ethics approval. This required creating an Online Participant Information Sheet and Consent Form (see Appendix F.1) and submitting it to the Ethics Approval Panel. This was done at the time of the previous user study ethics approval (for the low-fidelity prototype focus group evaluation) meaning all documents were submitted and approved at once.
2. **Preparation to Host Lab Session** Prior to the lab session, the following materials had to be created for the introduction to and evaluation of the high-fidelity prototype:
   (a) **Lab Session Slides** These consisted of a short slide show explaining the concept and usage of the tool to students using images and descriptions of the different tool screens and their functionality.
   (b) **Questionnaire Form** The questionnaire consisted of 5 mandatory Likert scale questions (statements with the options to answer ‘Strongly Agree’, ‘Agree’, ‘Neutral’, ‘Disagree’, or ‘Strongly Disagree’) followed by 4 optional open-ended questions. The creation of the questionnaire is discussed in Chapter 2.5 and the full list of questions and responses can be found in Appendices F.3 and F.2.
3. **Hosting Lab Session** The lab session took place in one of the large computing labs in the university informatics building (Appleton Tower). The slide show was put on the large projector screen at the front of the lab and once students had arrived they were taken through the presentation. At the end of the presentation was the URL to the high-fidelity prototype, as it was only 3 words long students could type this into their computers themselves before attempting the tool. Throughout the lab, students could ask questions and give feedback to myself and the project supervisor.
4. **Interpretation of Responses** Following the lab, the data from the questionnaire was collated and evaluated through the use of multiple visualisations.

5.5 Results and Analysis

It is important to note before exploring the results of the questionnaire, that Likert scale questions are prone to a "central tendency bias" [8]. This means that participants are less likely to select extremes (i.e. 'Strongly...') and the results usually peak in the central area of the scale. We will now evaluate each original aim through the analysis of the gathered questionnaire data (the full set of which can be found in Appendices F.3 and F.2):

Aim 1: Find out if students found the tool effective in their education and revision of UML diagrams in preparation for the SDM mid-term lab assessment.

The first aim was met through the results of the first 2 Likert scale questions in the questionnaire - "*My knowledge of UML models has improved.*" and "*I feel more confident for the mid-term lab assessment.*". The goal of both of these questions was to gather data about the high-fidelity prototype's impact on students' education and revision.



(a) Question 1 (b) Question 2

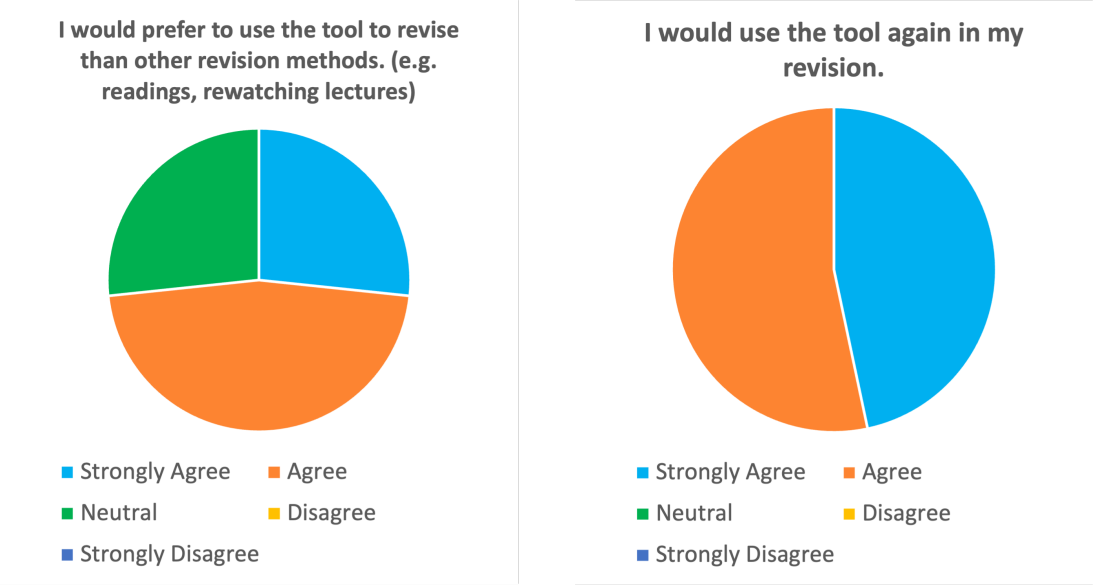
Figure 5.1: Student Answers to Questions 1 and 2

Question 1 (see results in Figure 5.1a) received only 'Strongly Agree' and 'Agree' responses. This allows us to draw a clear conclusion that students found that the high-fidelity prototype of the tool aided their education of UML models. Question 2 (see results in Figure 5.1b) received a more interesting response. Whilst it got a greater number of 'Strongly Agree' responses showing a more decisive agreement with the statement, it also received 1 'Disagree' response. However, the student that selected 'Disagree' responded to the last open-ended question (included to allow extra comments such as this) saying "*Admittedly I said I was less confident in the midterm, but I think that's more to do with Dunning-Kruger than anything else*". The Dunning-Kruger effect is the idea that individuals with a low understanding/knowledge of an area are more likely to overestimate their understanding/knowledge in that area [4].

Therefore, although question 2 received a 'Disagree' response this is likely because the tool led this student to realise how much they still had to learn in preparation for the mid-term lab assessment and so felt as though they knew less than when they started. This does not mean the tool did not help them prepare for the mid-term lab assessment but rather the opposite as now they understand the full extent of preparation that is required. Aim 1 has therefore been achieved as we have found that the tool received a nearly 100% agreement that students felt their knowledge and revision had been aided.

Aim 2: Find out if students liked using the tool as a form of revision in preparation for the SDM mid-term lab assessment.

The second aim was met through the results of the third and fourth Likert Scale Questions - "*I would prefer to use the tool to revise than other revision methods. (e.g. readings, rewatching lectures)*" and "*I would use the tool again in my revision.*". The goal of both of these questions was to gather data about the students' opinions on using the tool as a form of revision.



(a) Question 3 (b) Question 4

Figure 5.2: Student Answers to Questions 3 and 4

The most common response to question 3 (see results in Figure 5.2a) was 'Agree' followed by an equal split between 'Strongly Agree' and 'Neutral'. This response is understandable within the context - the tool alone would likely not be sufficient for revision as it does not cover all types of questions (e.g. questions involving Java) and therefore other tools are more appropriate for revision of all potentially assessed areas. The response to question 4 (see results in Figure 5.2b) is the most decisive response amongst all the Likert scale questions with 47% of students responding 'Strongly Agree' when asked if they would use the tool again and the other 53% responding 'Agree'. This shows a definitive response from students that they found the tool relevant/useful to their revision.

Therefore, Aim 2 has been met as conclusive data regarding students' opinions on the use of the tool as a revision material has been gathered. Overall, although students may not use the tool as their sole form of revision, they would definitely use it on more than 1 occasion in their revision showing they liked using it as a form of revision.

Aim 3: Find out if students found the tool usable and understandable.

The third aim was met through the results of the fifth Likert scale question - "*I found the tool easy to use.*" - in conjunction with the follow-up open-ended question - "*If for the above question (5) you disagree, please explain why.*". The goal of both of these questions was to investigate whether students were able to use the tool easily and if they were not, what issues they had.

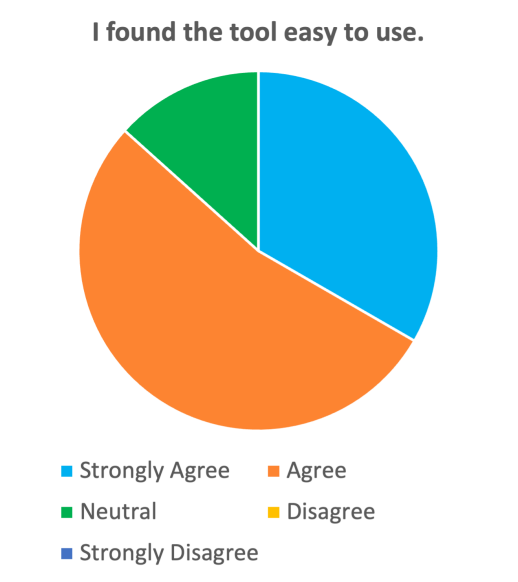


Figure 5.3: Student Answers to Question 5

The student responses to question 5 are shown in Figure 5.3. Whilst the majority of students agreed that the tool was easy to use, 2 students only selected neutral but provided comments explaining why in question 6. These responses are as follows:

"*I didn't realise that I can scroll down in the grey box, so I wouldn't be able to find the reveal answer button unless I asked for help.*"

"*I don't quite... disagree, the tool was intuitive to use but there were a number of times where answers were effectively duplicates of one another (further extrapolated on in improvements). Additionally, the first time reading through a question took a long time as all possible marker options had to be read and understood.*"

The first comment was an issue already considered in the tool design. As the scroll bar at the side of the feedback statement box was not always clearly visible there was a statement at the top of the box reading "scroll for more". However, it is understandable that without scrolling to the bottom of the box students may not know where to mark their selected statements and this is something that in future should be emphasised more

in the introductory presentation of the tool. The other option would be to put the mark and reveal buttons outside of the feedback statement box, however, this would have meant reducing the size of other components adding extra complexity to the page and so was not implemented.

The second comment related firstly to the content of the tool. Whilst some answers have similar errors and so similar applicable feedback statements, I chose to leave these in the tool as they represented common errors among students on the course. It was thought that the repetition of these errors would hopefully reduce current students' likelihood of also making these mistakes, however, any answers students did not want to evaluate could be skipped if students wanted. Secondly, the feedback mentions the quantity of information initially presented on the question screen. This was also considered during design and addressed by ensuring the feedback options were in the same order for every answer to the question. It is worth noting though, for future work, that perhaps having fewer feedback statements available may be a more effective implementation.

Overall, aim 3 is met as questions 5 and 6 provide data able to be used to improve the tool's usability in the future and overall concur that the high-fidelity prototype of the tool has a good standard of usability.

Aim 4: Find out what students liked about the tool.

This aim was met through question 7 - "*Was there anything you particularly liked about the tool?*". Meeting this aim and gathering results from question 7 was important so that these features could be protected and enhanced in future developments of the tool. The aspects liked by the students are as follows:

- The colour choices across the question screen including the red and green colouring for correct and incorrect selected statements.
- The aesthetic and look of the user interface of the tool, described as "*very professional looking and consistent*".
- The ability to enlarge and drag the answer image.
- The number of answers provided and the inclusion of correct answers.
- The interface being usable and "*intuitive*".

In terms of the concept of the tool, some of the following points were noted:

- "*I can train my knowledge of UML and check my understanding by finding errors in other people's answers and correcting them.*"
- "*I liked the format, matching the feedback to the answers helped understand common pitfalls in writing diagrams.*"
- "*I liked the intuitiveness and how we were able to see past examples of students' answers (likely with mistakes we ourselves would make) and feedback on the answers*"

These all show the tool concept was liked and found useful by the students.

Aim 5: Find out what improvements students would suggest for the tool.

This aim was met through question 8 - "*Are there any improvements you would like to see in the tool?*". This yielded responses from all participants and a total of 18 different suggested improvements. It is interesting to note, however, that only 6 of these suggested improvements were suggested by more than 1 student. Out of these 5, 1 improvement was suggested by 5 people, 2 improvements by 3 people, and 3 improvements by 2 people. This indicates that whilst there are lots of areas with potential for expansion/improvement none of them are essential/urgent. The issues underlying the improvements suggested by more than 1 student are listed below, as well as the most relevant issues noted by individual students, with justifications and solutions that were evaluated to have a positive impact on the tool if implemented (see comprehensive list in Appendix G):

- **Issues with consistency in tool content (mentioned by 5 students).**

  Solution: Although the project supervisor and I did attempt to clean the tool's data and note as many consistency issues as possible, there were still some that were missed. Several students suggested that to combat this a bug/error reporting button be implemented for each answer in the tool so that if students found inconsistencies they could be reported. This is a favourable suggestion and should be taken into consideration for future development of the tool.

- **No intuitive scrolling, mark feedback statement selection button not visible until scrolled (mentioned by 3 students).**

  Justification and Solution: Whilst this has already been discussed along with the students' solution (placing the mark and reveal correct statements buttons outside the feedback statement box) it is worth taking into consideration for future development of the tool having been mentioned by 3 students. Although it may increase the complexity of the page, it may in turn improve usability. Therefore, for future work, I would suggest investigating this feature in a user study.

- **Can only click on the checkbox associated with a feedback statement rather than the statement text itself (mentioned by 3 students).**

  Solution: This was a design feature that as a creator rather than a user of the tool I overlooked. Therefore, I would suggest the implementation of this in future development of the tool to aid usability.

- **No scoring for user success (at matching answers with feedback) at the end of the tool (mentioned by 2 students).**

  Justification: This subject was previously mentioned in the evaluation of the low-fidelity prototype with the project supervisor when they wanted marks for questions and answers to be removed from the tool. Therefore, it would not make sense to add them back and, to an extent, gamify the tool, possibly taking students' attention away from the revision aspect and leading them to focus more on achieving the highest score possible in the tool.

- **Enlarged student answer image still not big enough (mentioned by 2 students).**

Solution: Again this was an oversight on my part - viewing the tool as a creator rather than a user. Therefore, for future implementations, I would suggest the enlarged student answer image was not only draggable but also resizable.

- **No state continuity, i.e. the tool does not remember the state of feedback statement box between different student answers and/or when the correct answer is revealed. (mentioned by 2 students).**

  Solution: These are 2 separate suggestions with similar ideas. This had not been done in order to allow students to reattempt questions/answers. In terms of a solution/future developments, it would be a good idea to investigate this in a user study. Particularly, do students want their incorrect answers still in red when the correct answer is revealed and do they want their attempt to select feedback to be remembered after they move on answer/question?

- **No answer order randomization (mentioned by 1 student).**

  Justification/Solution: This suggestion was considered in the implementation of the tool (algorithm determining the order of questions/answers), however, not being essential for the main interface, there was not enough time for it to be implemented. Therefore, some kind of algorithm determining the order of the questions would be a recommended addition to the tool in future.

- **When a question is marked incorrect but all statements selected are correct, it's hard to know how many more statements to look for (mentioned by 1 student).**

  Solution: This suggestion was on the original list of features to implement but again time ran out before it could be implemented. Therefore, it would be a suggestion for future developments to add some kind of hint button for showing the number of feedback statements applicable to the current student answer.

- **There is no way to tell how many questions/answers are left to do and so there's no way to tell how far you have progressed through the tool (mentioned by 1 student).**

  Solution: As with the last issue this suggestion was on the original list of features to implement but again time ran out before it could be implemented. Therefore, it would be a suggestion for future development to add the number of questions/answers left to the next buttons as in the low-fidelity prototype.

- **The help screen contains a lot of information and so is hard to navigate (mentioned by 1 student).**

  Solution: Again, due to time constraints, the help page was not completed to the standard I had planned. However, as there was to be a presentation to describe the use of the tool to students before they attempted it, the help screen was less vital. However, it is a recommended future development to make the help screen interactive and more aesthetic and informative.

Chapter 6

Conclusions and Discussion

6.1 Research Questions

Having concluded the dissertation project, the research questions proposed in the dissertation introduction in Chapter 1 can be answered.

RQ1: What teaching tools currently exist for UML diagrams?

Currently, teaching tools for UML diagrams do exist. These include UML diagram creation tools, UML documentation, and UML quizzes, however, the SDM course only teaches specific content covering UML models as a part of the software design and modelling process. Therefore, the mid-term lab assessment questions are specific structures and so a tool tailored to the course is favourable.

RQ2: Is 'learning from errors' an effective teaching approach, particularly regarding UML diagrams?

Adopting a learning from errors approach has been found to be an effective way to teach. It has been found to increase student retention of knowledge [32] and increase student understanding of overall concepts [44]. Specifically regarding UML diagrams, it has also been found to be effective in previous studies [1] [35]. The tool created in this dissertation adopted a learning from errors approach and achieved a very positive response from students with them agreeing that they liked using it and found it easy to use as well as effective at improving their UML knowledge.

RQ3: How may an effective teaching tool for UML diagrams be created?

Background research showed that in addition to a learning from errors approach, online quizzes are an effective teaching approach for students. Therefore, these methods were used to create the tool.

From a technical perspective, the tool can be created in the way described below:

1. Create and evaluate a user interface design for the tool (low-fidelity prototype) to ensure an effective and usable layout for target users.

2. Gather anonymised data from the previous year's assessment (questions, answers, and feedback) and clean this to be used in the tool.
3. Implement the design using HTML, JavaScript and Bootstrap (high-fidelity prototype) and evaluate this with the target users, implementing any necessary changes.

RQ4.1: Do students find the tool improves their knowledge and understanding of UML diagrams?

In the user study of the high-fidelity prototype, every student agreed that their knowledge of UML diagrams had improved and all except one (who admitted this was due to prior over-confidence) felt more prepared for the mid-term lab assessment.

RQ4.2: Do students want to use the tool?

100% of students agreed that they would like to use the tool again with 73% of students agreeing that they preferred it to other revision methods. This shows that students firstly found the tool useful, as they would like to use it again, and secondly, most students wanted to use the tool agreeing it was their favourite method of revision.

RQ4.3: Do students find the tool easy to use?

87% of students agreed that they found the tool easy to use, with only 2 students remaining neutral because of certain functionality they struggled slightly more to understand.

RQ4: Do students on the Software Design and Modelling course find the new tool effective in regards to their education of UML diagrams?

This research question can now be answered using the responses from RQ4.1, 4.2, and 4.3. Overall, the tool was found to: aid students' education of UML diagrams and so their education in the SDM course, be liked by students as a revision technique, and be easy to use for students. This leads to the conclusion that, although there is room for improvement, the tool is effective in all areas.

6.2 Study Limitations

Throughout the course of this project I identified 3 areas which could have been improved:

- Firstly, the background research into tools for hosting front-end-only websites could have been more extensive. This would have meant time wasn't wasted using tools (W3Schools) not appropriate for the project (only allowing a certain number of files) and therefore would have saved time.
- Secondly, a larger number of focus group participants would have collated more extensive results for the evaluation of the low-fidelity prototype. Although this was an unavoidable issue for the current study it is worth noting in future (perhaps gathering student participants earlier in the semester when they have less coursework).

- Thirdly, a more thorough initial presentation of the tool could have been done and a more effective help screen implemented to avoid usability issues such as students not being able to find the button to mark their selected feedback statements.

6.3 Knowledge and Skills Developed

Throughout the project I developed knowledge and skills in the following areas:

1. **Literature Review** After completing a fairly extensive literature review in preparation for the commencement of the project, I have developed my research and academic writing skills.
2. **HTML/Bootstrap/JavaScript** With very little prior experience these were the skills that I developed the most. I can now create reasonably complex front ends of websites using these tools.
3. **User Studies** Having never previously hosted a user study or had to analyse collected data, I now feel confident in the process. The study involved the hosting of both an in-person focus group as well as an online questionnaire and gathering and analysing both qualitative and quantitative data allowing for the development of all of these skills.

6.4 Future Work

The project supervisor is proposing the advancement of the current tool as an honours year project for next year's Informatics final year students. This means that the project may be taken over by another student and further developments made. I, therefore, suggest the following:

- Rather than having all feedback statements relevant to each question displayed for every student answer, have only the most likely statements for that answer (the right statements along with other carefully selected decoy statements) to pose a greater challenge to students and not overwhelm them with statements. Keeping all feedback statements during data cleaning rather than just those relevant to the tool's student answers may be helpful here to allow more choice for decoy statements. Also relevant is the addition of more data to the tool, e.g., other year's lab assessments, or part C of the question paper.
- Automating the uploading of data to the tool. Whilst this was in the original project plan it was not reached in time for the tool's deployment and evaluation. However, it is a feature that would vastly improve the usability of the tool for the project supervisor and save them time. This may involve the use of a different hosting platform/employment of a back-end which may also be necessary if, eventually, files begin to exceed the 10GB limit on GitHub Pages.
- The use of algorithms within the tool to create an extra challenge for students. It may be an idea to have a number of different modes that the student can select

from - e.g. random, where the student is shown questions and answers in a random order, or increasing difficulty, where the student is shown easier questions and answers to begin with (i.e. answers that students guess the feedback correctly more often/complete in quicker time) that gradually increase in difficulty.

- There is also the opportunity to implement a feedback system for the student users rather than just marking the selected feedback statements. This may consist of the tool observing common errors the student is missing in student answers and notifying the student of this, or, giving advice as to why the student may have picked an incorrect feedback statement for a certain answer.
- Finally, the implementation of general user interface improvements. These include the features planned but not completed in this project - number of questions/answers still to go/already done displayed on buttons, hints offered to students indicating how many statements they need to select for each answer, and improvement of the help screen. These also may include the features noted by the student evaluation of the high-fidelity prototype - adding a bug reporting button, having statements be selectable and not just their checkboxes, and making the enlarged student answer image resizable. In addition, these may include aspects that still require some further investigation such as - the location of the mark selected feedback statements and reveal correct feedback statements buttons, or, state continuity between answers and questions.

If, however, the project is not taken on by another student, I have created a document for the project supervisor detailing the data upload process and have passed on the project files. (This can be located in Appendix H.)

6.5 Conclusion

Firstly, in this dissertation, background research was conducted to determine the efficacy of the planned tool implementation and how previous similar studies adopt certain methods and concepts. It was concluded that learning from errors was an effective and suitable approach to be used and so too was the form of an online quiz tool.

The dissertation then moved to the creation and evaluation of a low-fidelity prototype of the tool's main user interface. This chapter concluded that with certain adjustments suggested by the supervisor and focus group participants, the current design and concept would likely be suitable and effective for students on the SDM course to use in their revision for the mid-term lab assessment.

Finally, a high-fidelity prototype was implemented and evaluated. These chapters concluded that whilst there are improvements and extensions that could be made to the tool, the current implementation was liked by students as well as being found effective and usable.

Overall, this dissertation can conclude that an online quiz adopting a learning from errors approach is an effective revision tool for students on the SDM module to aid their locating and spotting of errors in UML diagrams.

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Appendix A

Previous Year Mid-Term Lab Assessment Data

A.1 Mid-Term Lab Assessment Question Paper

Lab assessment for Software Design and Modelling

Week 6, Semester 1, 2021

- This assessment is to be done **individually**, making use of the tools you have used in the lab sessions so far.
- It is **open-book**: you may consult the course material and any online source you have found useful. However, you may not collaborate with one another or with anyone else.
- Please remember the **good scholarly practice** requirements of the University regarding work for credit. You can find guidance at the School page

  `https://web.inf.ed.ac.uk/infweb/admin/policies/academic-misconduct`

  which also has links to the relevant University pages. Please do not publish solutions to these exercises on the internet or elsewhere, until I tell you you may.
- The exercise has been designed to be done in **75 minutes**. Those given 25% extra time in exams may use 94 minutes, according to their usual arrangements.
- The assessment will be **marked out of 20**. It is in three parts.
  - Part A is worth 10 marks, and is intended to take no more than 30 minutes, provided you understand the work and the tools well.
  - Part B is worth 6 marks. You are advised not to work on it until you are confident that you have done Part A well. It is intended to take no more than 30 minutes for those who understand the work and the tools very well, but might take up to 45 minutes with a few false steps.
  - Part C is worth 4 marks. It is intended to challenge those students who find parts A and B easy and do them fast. Don't worry if you don't get to it: as you see, a first-class mark can be obtained without attempting it. You are advised not to attempt it *unless and until* you feel you have done Parts A and B very well. **It will not be marked unless your Parts A and B have already earned you a first-class mark.**

To submit

Each question tells you what to submit, giving a filename and format, e.g. A1.pdf. Save your files locally. Then when you are ready to submit, make a zip file called `done.zip`, containing them all, and upload it using the button in the question where you got this paper. *Use exactly the names and formats specified*, otherwise you may lose marks.

Part A

1. In LucidChart draw a UML class diagram showing:

   - a class Participant with a private attribute name of type String and a public operation join taking a VideoCall as argument and returning a boolean
   - an abstract class VideoCall
   - concrete subclasses ZoomCall and TeamsCall of VideoCall
   - an appropriate relationship between VideoCall, ZoomCall and TeamsCall
   - an appropriate relationship between Participant and VideoCall, demonstrating that at any one time a given participant can be in at most one video call, while a video call may have any number of participants (including zero, say, to account for scheduled calls).

   Export your diagram as A1.pdf

   (6 marks)

2. Using SequenceDiagram.org, draw a sequence diagram showing lifelines for an actor called s of type Scheduler and for two Participants called p1 and p2. Show that s creates a ZoomCall and then causes first p1 and then p2 to join it: show that they do so successfully.

   Your diagram should illustrate just the example behaviour described: do not use fragments, do not concern yourself with error behaviour. There is no need to show activation bars.

   Save Source Text as A2.txt *and also* export the PNG Image File as A2.png - include both files in your zip for submission.

   (4 marks)

Part B

This multi-part question produces a single LucidChart diagram which you will export as B.pdf.

Note: you will probably need to enrich the sets of attributes and operations of the Participant class slightly. Do not modify the class diagram you drew earlier. Instead, include in your diagram (e.g. as a Note, a UML comment) a list of any extra attributes and operations you need to add. Only add things you need in order to answer this question.

1. In LucidChart, draw a nested state diagram for class Participant indicating that a participant can be in a call or not, and that if they are in a call, they may be muted or not. Make the mute setting "sticky" in the sense that if the participant leaves and then joins, they will be muted if and only if they were muted when they left. A newly-created Participant should not be on a call. The default state on entering a call for the first time should be muted.

   Include events on transitions, but do not include actions.

   (3 marks)

2. In the same diagram, add:

   (a) An OCL constraint, placed in an appropriate state of your diagram, describing what it means that the participant is not in a call. (That is, defining the state in terms of the object's properties.)

   (1 mark)

   (b) An OCL guard on the transition corresponding to the participant unmuting, to indicate that they can only do this if no other participant on the same call is unmuted.

   (2 marks)

   Your constraints may use any relevant properties from your Part A class diagram; if you need to use extra properties, make sure they are included in the Note mentioned above.

Export your diagram as B.pdf.

Part C

REMINDER: This part is intended for students in the upper reaches of the University Standard Marking Scale. It is aimed at students who have found Parts A and B easy and done them quickly. It will only be marked if your answers to Parts A and B have already secured you a first-class mark! So you are strongly advised not to attempt it until you are sure you have done as well as you can on Parts A and B.

Recall the investigation into tools that you did as part of the Week 4 lab. Pick one UML tool (*not* one of those mentioned in the Week 2 or Week 3 labs) which you investigated and found particularly interesting for some reason. Perhaps it is for a positive reason, to do with its usability or an unusual capability that it has? Or perhaps it is for a negative reason, such as its inability to draw UML diagrams that are formally correct, in some way?

1. Give its name and URL.
2. **In no more than 200 words**, explain why you think this tool is particularly interesting.
3. Give one UML diagram made in your chosen tool, to illustrate what you say.

File names and formats you submit for this question may be whichever are convenient for you from:

- C.pdf
- C.docx
- C.txt
- C.png
- C.jpg

Rule: Do not submit files with any other name or format; they will not be marked. If (unlikely!) your tool cannot export a diagram as any of the given formats, taking a screenshot of the diagram in the tool is an acceptable way to produce your file.

My preference: If you submit your text as a .pdf or a .docx, it would be convenient for me if you embed your diagram in the document along with your text, so that you submit only the one file. If you prefer to submit a .txt rather than a .pdf or .docx, of course you'll need to submit a separate file (as .png, .jpg or .pdf) containing your diagram.

A.2 Mid-Term Lab Assessment Example Student Answers

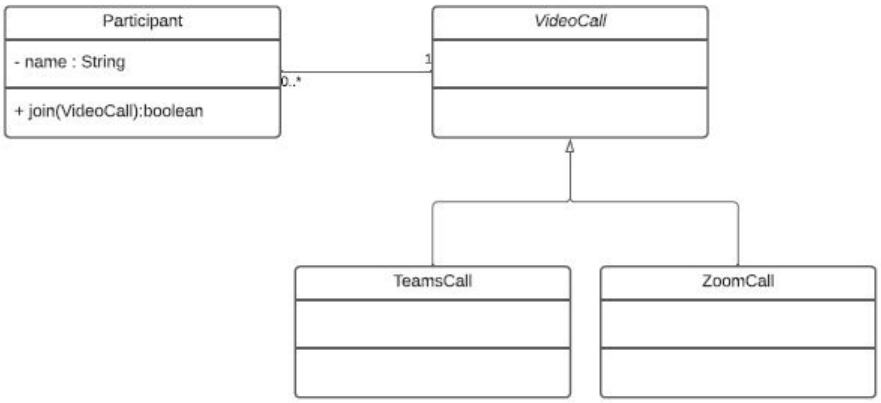

Figure A.1: Example Student Answer A1

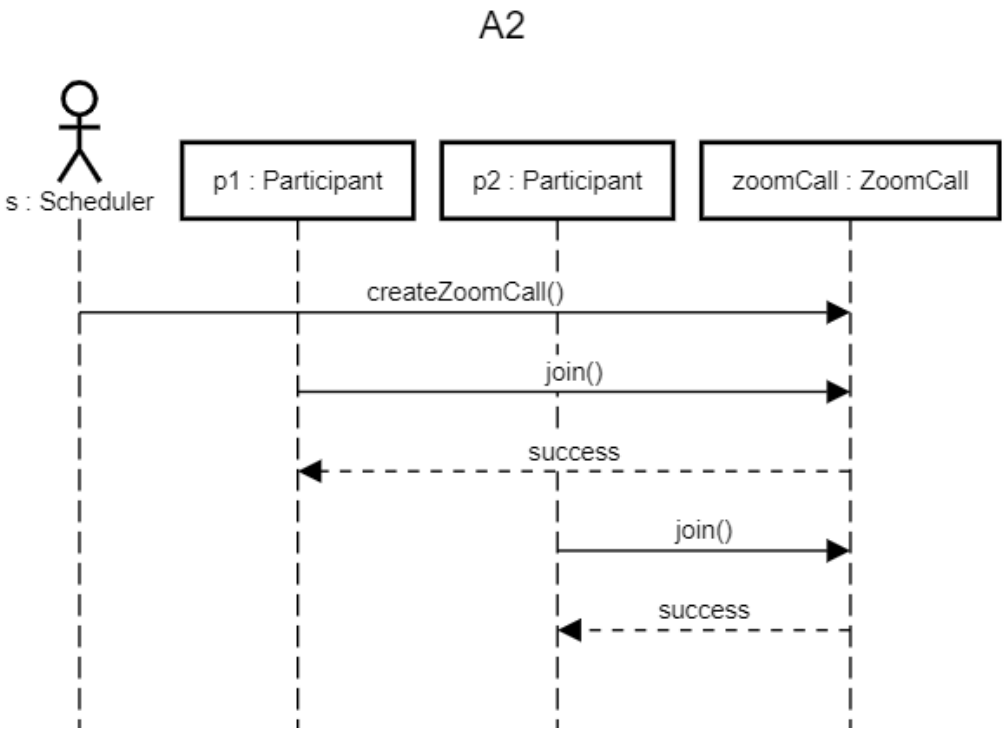

Figure A.2: Example Student Answer A2

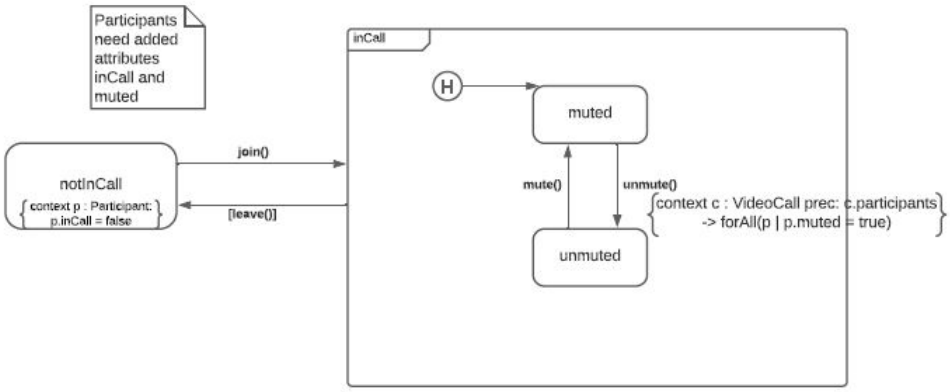

Figure A.3: Example Student Answer B

A.3 Mid-Term Lab Assessment Excerpt of Raw Collated Feedback

A1

Perfect!

Don't submit a diagram containing dummy entries like attribute1.

State that name is private, using - (yes, it's tricky in the tool, see solution video for one way!)

...

Superfluous extra class.

Really you should name the association (or alternatively the association ends).

This is a long way from right: look at the solution video and revise the class diagram material.

==========

A2

Perfect!

Missing types in lifelines: you need e.g. p1:Participant

You need colons in the lifelines e.g. p1:Participant

...

This is a bit confused. For example, the actor (not something else unseen) should start the interaction, which should involve creation of a ZoomCall object and the join messages that you already know about from A1; and the return from p1 should happen before the message to p2.

Label the creation message <<create>> - see solution video.

You've invented the connect message, though it's quite a reasonable thing to invent.

==========

B1

Good

Only the corners of the states should be rounded (not the whole sides).

You need a start pseudostate with a transition into the not in call state.

...

You've added operations not just attributes - and why is leave() in []?

No, this isn't close to what was asked for. Watch the model solution video, and revise the state diagram material.

Show In Call *as* a nested state, rather than having an unlabelled transition between two states both called In Call!

==========

B2

OCL excellent - this turned out to be hard for almost everyone!

OCL: missing

OCL: an attempt, but not close enough to correct for marks I'm afraid.

...

Your guard's a little over-complicated but does work!

For not in a call all that you needed was a constraint in placed in the state - see solution videos.

Good attempt at the OCL even though it isn't quite right!

==========

C

3 marks:

Interesting, good comments.

2 marks:

A good point!

Do note that your UML diagram isn't actually correct UML though! (UML doesn't have text inside its decision diamonds, as flow charts may.)

==========

no submission

Appendix B

Low-Fidelity Prototype Screens

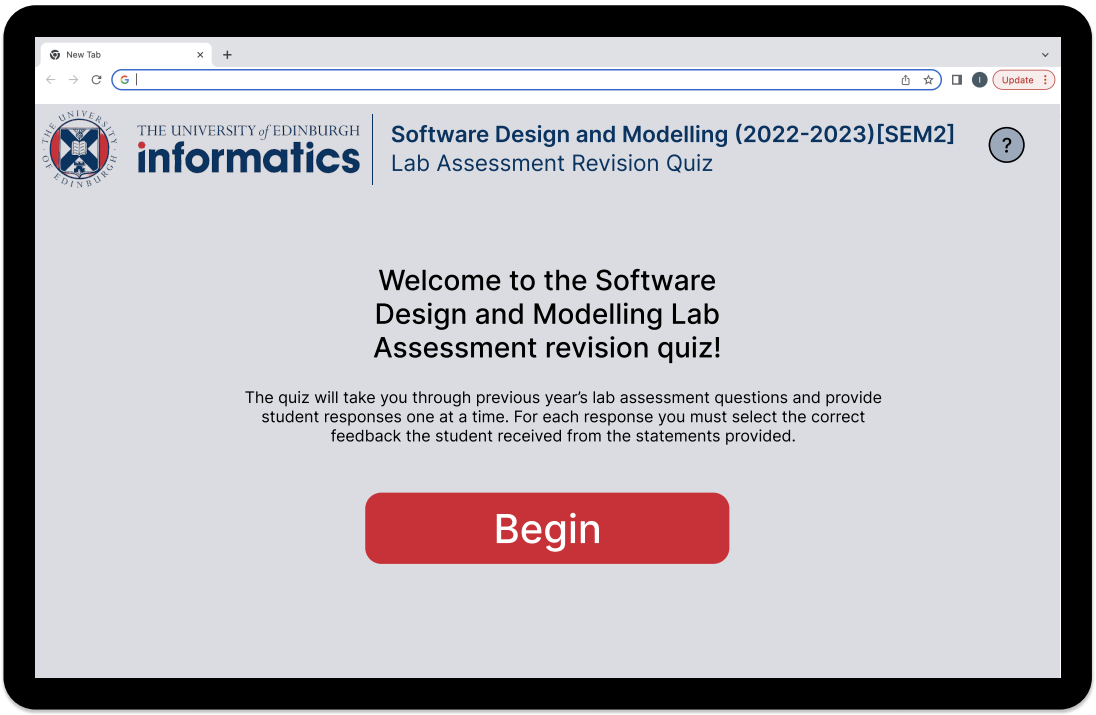

Figure B.1: Low-Fidelity Prototype Start Screen

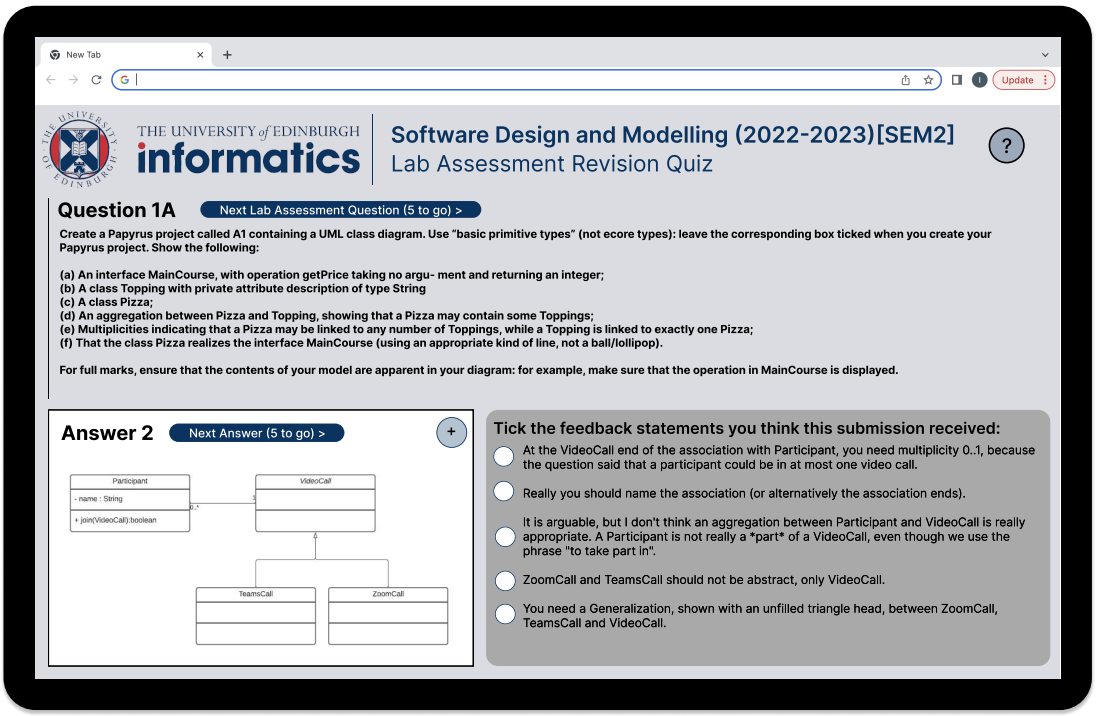

Figure B.2: Low-Fidelity Prototype Initial Question Screen

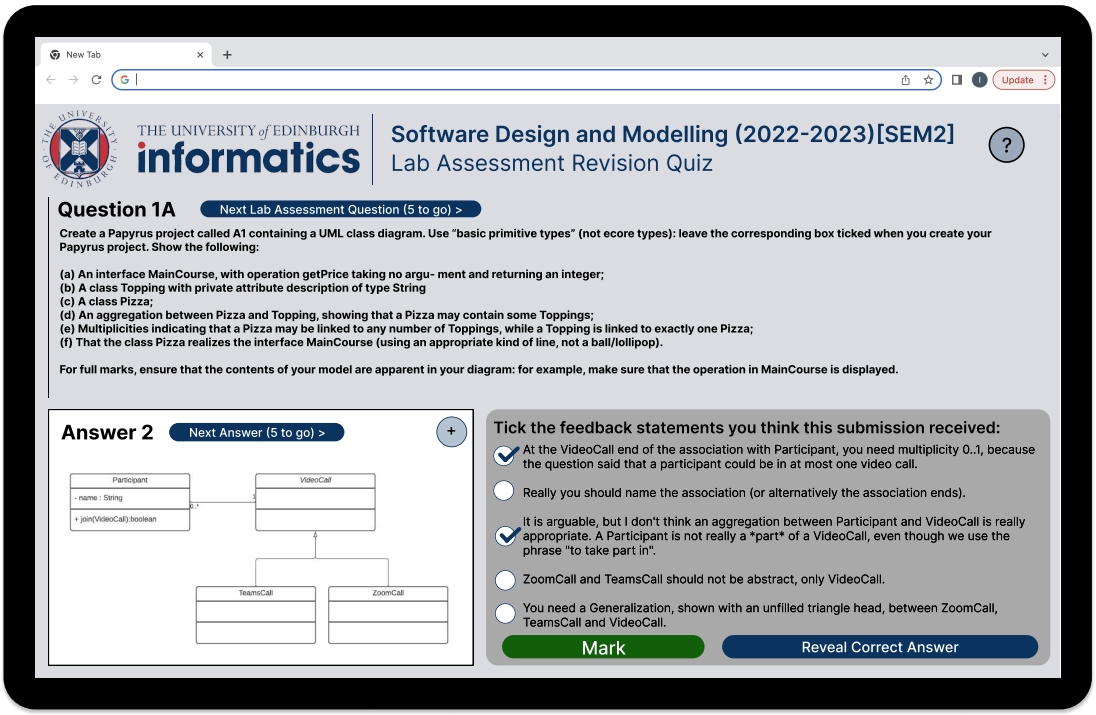

Figure B.3: Low-Fidelity Prototype Selected Statements Question Screen

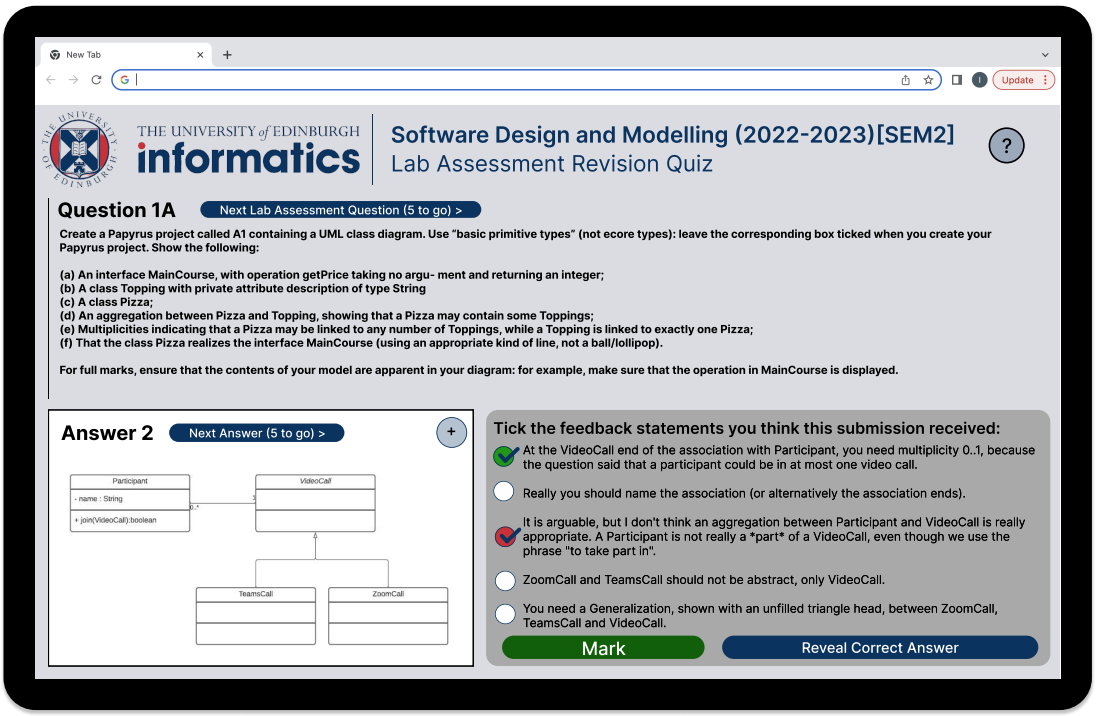

Figure B.4: Low-Fidelity Prototype Marked Selected Statements Question Screen

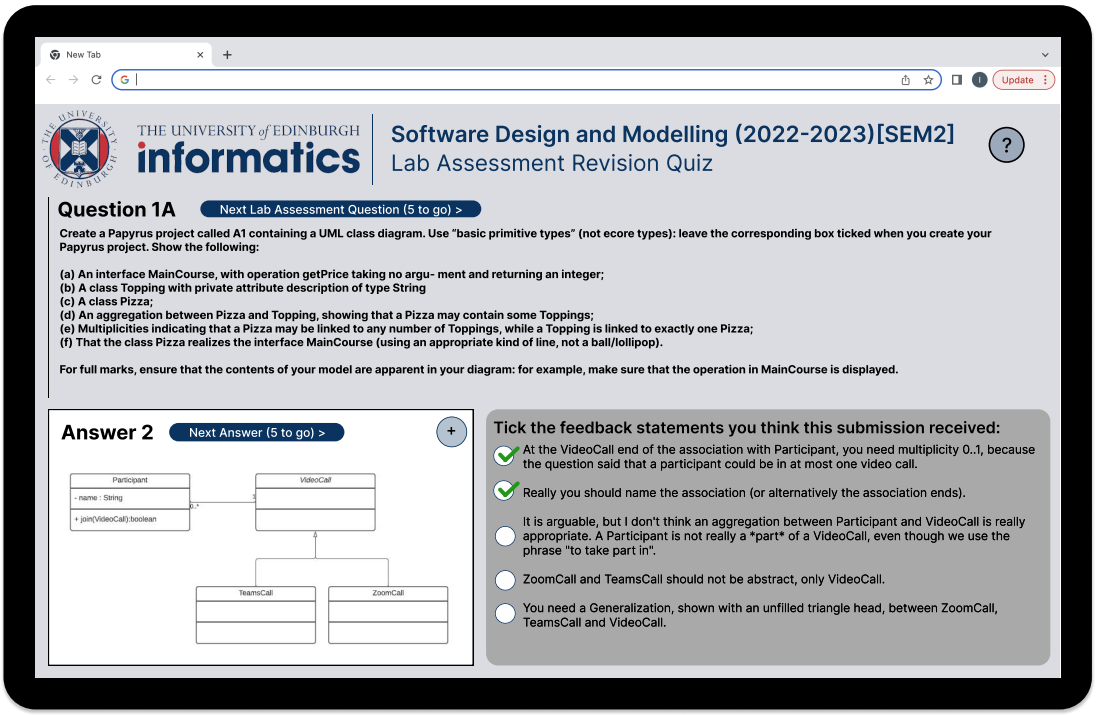

Figure B.5: Low-Fidelity Prototype Reveal Correct Statements Question Screen

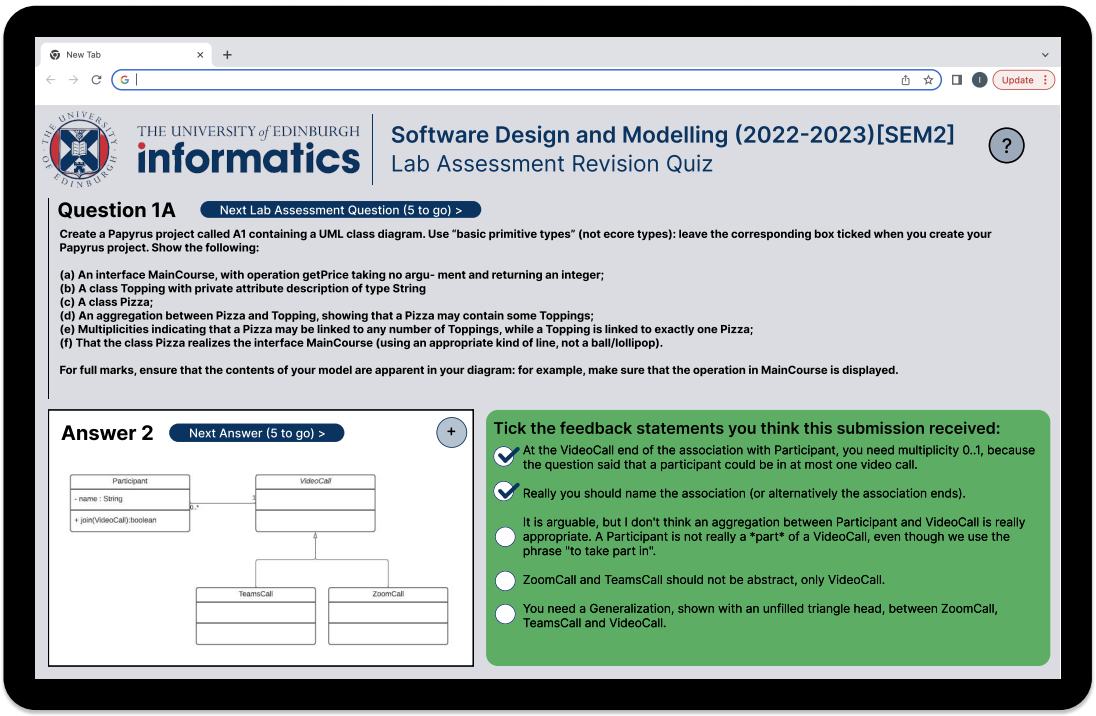

Figure B.6: Low-Fidelity Prototype Selected Correct Statements Question Screen

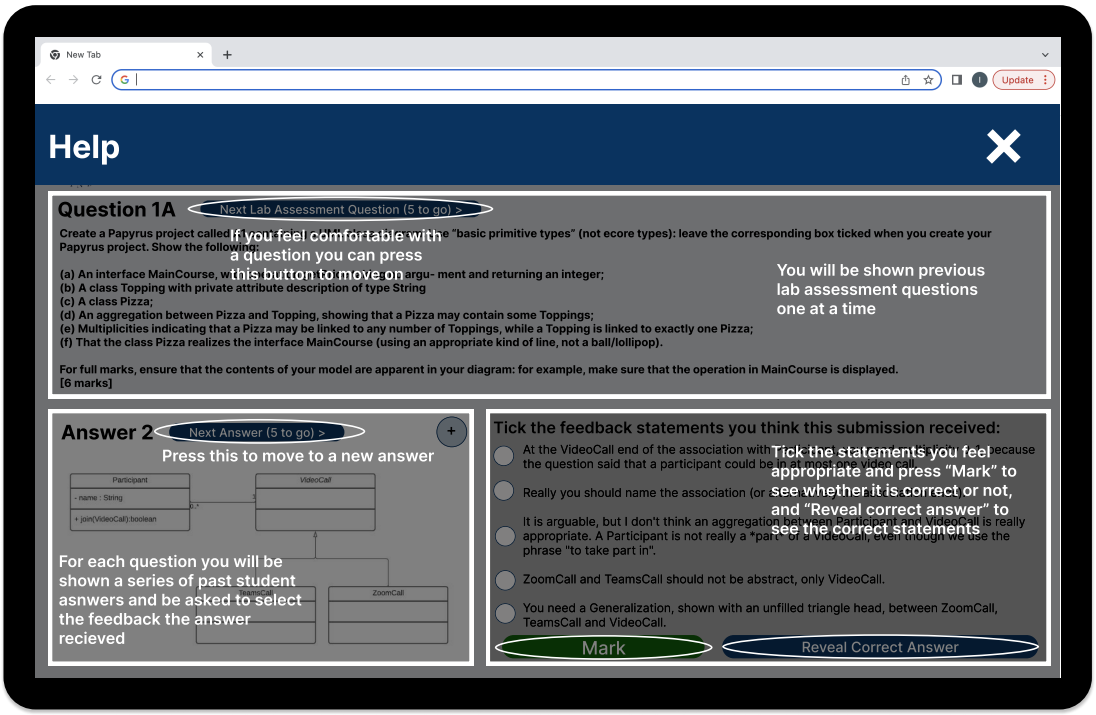

Figure B.7: Low-Fidelity Prototype Help Screen

Appendix C

Focus Group

C.1 Participant Information Sheet

C.2 Consent Form

C.3 Agenda

Participant Information Sheet

Project title:	Creating a Tool to Help Students on the Software Design and Modelling Course Identify Problems in UML (Unified Modelling Language) Models
Principal investigator:	Perdita Stevens
Researcher collecting data:	Iona Cooper
Funder (if applicable):	N/A

This study was certified according to the Informatics Research Ethics Process, RT number #7139. Please take time to read the following information carefully. You should keep this page for your records.

Who are the researchers?

Iona Cooper (4th Year Undergraduate Student)

Perdita Stevens (Project Supervisor)

What is the purpose of the study?

The aim of the study is to gather information on past Software Design and Modelling students experience of the mid-term lab assessment as well as gather their thoughts and opinions on the proposed designs of the revision tool. This will aid the researcher in creating a design suitable and appealing for the current Software Design and Modelling students.

Why have I been asked to take part?

You have been asked to take part as you previously took the Software Design and Modelling course and volunteered to be part of a focus group.

Do I have to take part?

No – participation in this study is entirely up to you. You can withdraw from the study at any time, up until April 2023 without giving a reason. After this point, personal data will be deleted and anonymised data will be combined such that it is impossible to remove individual information from the analysis. Your rights will not be affected. If

you wish to withdraw, contact the PI. We will keep copies of your original consent, and of your withdrawal request.

What will happen if I decide to take part?

Taking part means you will be part of a focus group made of 2021 Software Design and Modelling students. The focus group will take 1-2 hours and involve firstly discussions surrounding students experience of the Software Design and Modelling Course, specifically the mid-term lab assessment, followed by discussions about proposed designs of the user interface for the revision tool.

The session will be recorded, audio only. Following the session, the recording will be transcribed to enable data anonymisation before use.

Are there any risks associated with taking part?

There are no significant risks associated with participation.

Are there any benefits associated with taking part?

There are no significant benefits associated with participation.

What will happen to the results of this study?

The results of this study may be summarised in published articles, reports and presentations. Quotes or key findings will be anonymized: We will remove any information that could, in our assessment, allow anyone to identify you. With your consent, information can also be used for future research. Your data may be archived for a maximum of 1 year. All potentially identifiable data will be deleted within this timeframe if it has not already been deleted as part of anonymization.

Data protection and confidentiality.

Your data will be processed in accordance with Data Protection Law. All information collected about you will be kept strictly confidential. Your data will be referred to by a unique participant number rather than by name. Your data will only be viewed by the researcher/research team.

All electronic data will be stored on a password-protected encrypted computer, on the School of Informatics' secure file servers, or on the University's secure encrypted

cloud storage services (DataShare, ownCloud, or Sharepoint) and all paper records will be stored in a locked filing cabinet in the PI's office. Your consent information will be kept separately from your responses in order to minimise risk.

What are my data protection rights?

The University of Edinburgh is a Data Controller for the information you provide. You have the right to access information held about you. Your right of access can be exercised in accordance Data Protection Law. You also have other rights including rights of correction, erasure and objection. For more details, including the right to lodge a complaint with the Information Commissioner's Office, please visit www.ico.org.uk. Questions, comments and requests about your personal data can also be sent to the University Data Protection Officer at dpo@ed.ac.uk.

Who can I contact?

If you have any further questions about the study, please contact the lead researcher, Iona Cooper at s1940351@ed.ac.uk.

If you wish to make a complaint about the study, please contact inf-ethics@inf.ed.ac.uk. When you contact us, please provide the study title and detail the nature of your complaint.

Updated information.

If the research project changes in any way, an updated Participant Information Sheet will be made available on http://web.inf.ed.ac.uk/infweb/research/study-updates.

Alternative formats.

To request this document in an alternative format, such as large print or on coloured paper, please contact Iona Cooper at s1940351@ed.ac.uk.

General information.

For general information about how we use your data, go to: edin.ac/privacy-research

Participant number:_____

Participant Consent Form

Project title:	Creating a Tool to Help Students on the Software Design and Modelling Course Identify Problems in UML (Unified Modelling Language) Models
Principal investigator (PI):	Perdita Stevens
Researcher:	Iona Cooper
PI contact details:	perdita@inf.ed.ac.uk

By participating in the study you agree that:

- I have read and understood the Participant Information Sheet for the above study, that I have had the opportunity to ask questions, and that any questions I had were answered to my satisfaction.
- My participation is voluntary, and that I can withdraw at any time without giving a reason. Withdrawing will not affect any of my rights.
- I consent to my anonymised data being used in academic publications and presentations.
- I understand that my anonymised data will be stored for the duration outlined in the Participant Information Sheet.

Please tick yes or no for each of these statements.

1.	I agree to being audio recorded.	**Yes** ☐	**No** ☐
2.	I allow my data to be used in future ethically approved research.	**Yes** ☐	**No** ☐
3.	I agree to take part in this study.	**Yes** ☐	**No** ☐

Name of person giving consent	Date dd/mm/yy	Signature
_____	_____	_____
Name of person taking consent	Date dd/mm/yy	Signature
_____	_____	_____

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Creating a Tool to Help Students on the Software Design and Modelling Course Identify Problems in UML (Unified Modelling Language) Models

Iona Cooper, s1940351, Final Year Project

Focus Group Agenda

1. Participant information sheets and consent forms.
2. Thank participants for attending.
3. Give overview.
    a. Will be audio recording and transcribing – transcript will be anonymous.
    b. Group to discuss software design and modelling course as part of project.
    c. Particularly focussing on lab assessment (give recap).
    d. Would also like opinions on low-fidelity prototype of proposed tool.
4. Begin with the mid-term lab assessment.
    a. Did participants find the lab assessment challenging.
    b. If so, why.
    c. Was the content challenging.
    d. How did participants prepare – was this effective.
    e. How would participants advise future students regarding the lab assessment.
5. Move discussion to lab assessment tool.
    a. Would you have found a revision tool useful, would you have used one.
    b. Explain tool.
    c. Go through Figma.
    d. Best and worst thing about the tool.
    e. Potential improvements.
    f. Would you have used the tool, would you recommend it to future students.
6. Thank students for their time.

Appendix D

High-Fidelity Prototype Data Storage Structure

```
const questions = [
    {
        number: 'Question A1',
        question: 'In LucidChart draw a UML class diagram showing: \n(a) a class Participant with a private attribute name of type String and a public operation join taking a VideoCall as argument and returning a boolean \n(b) an abstract class VideoCall \n(c) concrete subclasses ZoomCall and TeamsCall of VideoCall \n(d) an appropriate relationship between VideoCall, ZoomCall and TeamsCall \n(e) an appropriate relationship between Participant and VideoCall, demonstrating that at any one time a given participant can be in at most one video call, while a video call may have any number of participants (including zero, say, to account for scheduled calls).\n\n',
        answers: [
            { image: '/2021/StudentA/done/A1.JPG', correct: [4, 9] },
            { image: '/2021/StudentB/done/A1.JPG', correct: [5, 4, 9] },
            { image: '/2021/StudentC/done/A1.JPG', correct: [1] },
            { image: '/2021/StudentD/done/A1.JPG', correct: [3, 4, 6] },
            { image: '/2021/StudentE/done/A1.JPG', correct: [4, 9] },
            { image: '/2021/StudentF/done/A1.JPG', correct: [9] },
            { image: '/2021/StudentG/done/A1.JPG', correct: [3, 9] },
            { image: '/2021/StudentH/done/A1.JPG', correct: [2, 4, 9] },
            { image: '/2021/StudentI/done/A1.JPG', correct: [2, 9] },
            { image: '/2021/StudentJ/done/A1.JPG', correct: [4, 9] },
            { image: '/2021/StudentK/done/A1.JPG', correct: [4, 9] },
```

```
            { image: '/2021/StudentL/done/A1.JPG', correct: [9] },
            { image: '/2021/StudentM/done/A1.JPG', correct: [4, 9]
               },
            { image: '/2021/StudentN/done/A1.JPG', correct: [7, 8,
               9] },
            { image: '/2021/StudentO/done/A1.JPG', correct: [9] },
            { image: '/2021/StudentP/done/A1.JPG', correct: [9] },
            { image: '/2021/StudentQ/done/A1.JPG', correct: [4, 8,
               9] },
            { image: '/2021/StudentR/done/A1.JPG', correct: [4, 9] }
        ],
        checkOptions: [
            { id: '1', text: "Perfect!"},
            { id: '2', text: "You need a Generalization, shown with
               an unfilled triangle head, between ZoomCall,
               TeamsCall and VideoCall. If you use a -> head you are
                showing a navigable Association which is a
               completely different thing."},
            { id: '3', text: "You're showing interface realization
               with the dashed line, not generalization - given that
                VideoCall is an abstract class not an interface the
               latter is what you need."},
            { id: '4', text: "At the VideoCall end of the
               association with Participant, you need multiplicity
               0..1, because the question said that a participant
               could be in at most one video call."},
            { id: '5', text: "You're showing a dependency between
               Participant and VideoCall not an Association. Now
               there always is a dependency when there's an
               association - but dependency is not an instance-level
                concept so it doesn't then make sense to put
               multiplicities on a dependency arrow."},
            { id: '6', text: "You do not have information about
               navigability, so probably better not to show any."},
            { id: '7', text: "ZoomCall and TeamsCall should not be
               abstract, only VideoCall."},
            { id: '8', text: "It is arguable, but I don't think an
               aggregation between Participant and VideoCall is
               really appropriate. A Participant is not really a *
               part* of a VideoCall, even though we use the phrase
               \"to take part in\"."},
            { id: '9', text: "Really you should name the association
                (or alternatively the association ends)."}
        ]
    },
    {
        number: 'Question A2',
        question: 'Using SequenceDiagram.org, draw a sequence
           diagram showing lifelines for an actor called s of type
           Scheduler and for two Participants called p1 and p2. Show
            that s creates a ZoomCall and then causes first p1 and
           then p2 to join it: show that they do so successfully. \
           nYour diagram should illustrate just the example
           behaviour described: do not use fragments, do not concern
            yourself with error behaviour. There is no need to show
           activation bars.\n\n',
```

```
        answers: [
            { image: '/2021/StudentA/done/A2.png', correct: [8, 9, 12] },
            { image: '/2021/StudentB/done/A2.png', correct: [2, 6, 8, 10, 9, 15] },
            { image: '/2021/StudentC/done/A2.png', correct: [8, 13] },
            { image: '/2021/StudentD/done/A2.png', correct: [8] },
            { image: '/2021/StudentE/done/A2.png', correct: [11] },
            { image: '/2021/StudentF/done/A2.png', correct: [1] },
            { image: '/2021/StudentG/done/A2.png', correct: [9, 19] },
            { image: '/2021/StudentH/done/A2.png', correct: [3, 8, 10] },
            { image: '/2021/StudentI/done/A2.png', correct: [2, 5, 8, 11, 10, 14] },
            { image: '/2021/StudentJ/done/A2.png', correct: [8] },
            { image: '/2021/StudentK/done/A2.png', correct: [8, 4, 20] },
            { image: '/2021/StudentL/done/A2.png', correct: [7, 8, 10, 16] },
            { image: '/2021/StudentM/done/A2.png', correct: [14, 17] },
            { image: '/2021/StudentN/done/A2.png', correct: [8] },
            { image: '/2021/StudentO/done/A2.png', correct: [1] },
            { image: '/2021/StudentP/done/A2.png', correct: [8] },
            { image: '/2021/StudentQ/done/A2.png', correct: [8, 18] },
            { image: '/2021/StudentR/done/A2.png', correct: [8, 14] }
        ],
        checkOptions: [
            { id: '1', text: "Perfect!"},
            { id: '2', text: "Missing types in lifelines: you need e
                .g. p1:Participant"},
            { id: '3', text: "The instance of scheduler was supposed
                 to be an actor, so show it as such with a stick
                figure."},
            { id: '4', text: "Only the scheduler is an actor."},
            { id: '5', text: "Use ordinary rectangular instances
                unless told otherwise - the robustness diagram
                symbols are not standard in UML."},
            { id: '6', text: "You create an instance of ZoomCall so
                show the lifeline as an instance."},
            { id: '7', text: "ZoomCall is a class name not an
                instance name!"},
            { id: '8', text: "Object creation not shown correctly."
                },
            { id: '9', text: "The source of both join messages
                should be the scheduler."},
            { id: '10', text: "Use the join method that you already
                know about from A1."},
            { id: '11', text: "It is the scheduler, not the call,
                that has to send messages to the participants."},
            { id: '12', text: "join is a method on Participant, not
                ZoomCall: your message is going in the wrong
```

```
                direction."},
73              { id: '13', text: "Don't write p1.join etc. - the
                    diagram already shows that the message is going to p1
                    ."},
74              { id: '14', text: "Don't forget the argument to join:
                    you must pass the very same ZoomCall object that you
                    just created."},
75              { id: '15', text: "Use the solid arrow head for
                    synchronous messages."},
76              { id: '16', text: "Why would a message ever have its own
                     recipient as an argument?"},
77              { id: '17', text: "Don't destroy the ZoomCall - you were
                     not told to. NB a <<create>> is special - you do not
                     need to show a reply to it."},
78              { id: '18', text: "You've invented the connect message,
                    though it's quite a reasonable thing to invent."},
79              { id: '19', text: "Check the notation for return arrows.
                    "},
80              { id: '20', text: "You've invented the enterCall message
                    , though it's quite a reasonable thing to invent."}
81          ]
82      },
83      {
84          number: 'Question B1',
85          question: 'This multi-part question produces a single
                LucidChart diagram. \nNote: you will probably need to
                enrich the sets of attributes and operations of the
                Participant class slightly. Do not modify the class
                diagram you drew earlier. Instead, include in your
                diagram (e.g. as a Note, a UML comment) a list of any
                extra attributes and operations you need to add. Only add
                 things you need in order to answer this question. \n1.
                In LucidChart, draw a nested state diagram for class
                Participant indicating that a participant can be in a
                call or not, and that if they are in a call, they may be
                muted or not. Make the mute setting "sticky" in the sense
                 that if the participant leaves and then joins, they will
                 be muted if and only if they were muted when they left.
                A newly-created Participant should not be on a call. The
                default state on entering a call for the first time
                should be muted. \nInclude events on transitions, but do
                not include actions.\n\n',
86          answers: [
87              { image: '/2021/StudentA/done/B.JPG', correct: [2, 5,
                    14] },
88              { image: '/2021/StudentB/done/B.JPG', correct: [6, 15]
                    },
89              { image: '/2021/StudentC/done/B.JPG', correct: [5] },
90              { image: '/2021/StudentD/done/B.JPG', correct: [5, 7] },
91              { image: '/2021/StudentE/done/B.JPG', correct: [9] },
92              { image: '/2021/StudentF/done/B.JPG', correct: [1] },
93              { image: '/2021/StudentG/done/B.JPG', correct: [7, 8] },
94              { image: '/2021/StudentH/done/B.JPG', correct: [15, 13]
                    },
95              { image: '/2021/StudentI/done/B.JPG', correct: [1] },
96              { image: '/2021/StudentJ/done/B.JPG', correct: [5] },
```

```
97              { image: '/2021/StudentK/done/B.JPG', correct: [16] },
98              { image: '/2021/StudentL/done/B.JPG', correct: [5, 7] },
99              { image: '/2021/StudentM/done/B.JPG', correct: [7, 10]
                    },
100             { image: '/2021/StudentN/done/B.JPG', correct: [7] },
101             { image: '/2021/StudentO/done/B.JPG', correct: [1] },
102             { image: '/2021/StudentP/done/B.JPG', correct: [8] },
103             { image: '/2021/StudentQ/done/B.JPG', correct: [11, 12]
                    },
104             { image: '/2021/StudentR/done/B.JPG', correct: [4, 5, 3]
                     }
105         ],
106         checkOptions: [
107             { id: '1', text: "Good."},
108             { id: '2', text: "You need a start pseudostate with a
                    transition into the not in call state."},
109             { id: '3', text: "No event is needed on the transition
                    from the start state (this is just object creation)."
                    },
110             { id: '4', text: "There wasn't information about a
                    transition to a final state, and it is not obligatory
                     for state diagrams to have such transitions: don't
                    invent."},
111             { id: '5', text: "Arrow heads on transitions in state
                    diagrams should be -> not LucidChart's default solid
                    triangle or anything else."},
112             { id: '6', text: "Why did you add joinCall when there's
                    already a join??"},
113             { id: '7', text: "Be clear that the labels on your
                    transitions are events, in this case, message calls.
                    E.g. use exactly join(v), and where you invent new
                    method names, use consistent capitalisation and make
                    sure what you use on the transitions is exactly
                    consistent with what you have in your class diagram
                    and your note about what else you are adding."},
114             { id: '8', text: "I wonder whether you really understand
                     how history states work? You seem to be trying to
                    duplicate its effect."},
115             { id: '9', text: "I wonder whether you really understand
                     how history states work? You are circumventing its
                    effect by having your transition into the superstate
                    bypass it."},
116             { id: '10', text: "The extra state you have immediately
                    after the start state is redundant - note in
                    particular that it has no event on the transition
                    leading out of it, which is a warning sign. Just
                    leave it out and put the start state transitioning
                    directly into not on a call."},
117             { id: '11', text: "Correct but can be done a little more
                     simply, see solution video."},
118             { id: '12', text: "NB the videoCall property of
                    Participant already exists - you aren't inventing it!
                    "},
119             { id: '13', text: "The state diagram is for Participant,
                     so the call events in it are methods of Participant,
                     not VideoCall."},
```

```
            { id: '14', text: "You've added operations not just attributes - and why is leave() in []?"},
            { id: '15', text: "You were told not to add things you didn't need, so you should not add a new attribute to represent whether the participant is in a call: that is already there in the property that is the association end connecting Participant to VideoCall in your class diagram."},
            { id: '16', text: "Show brackets after the message names e.g. join(), as these are call events."}
        ]
    },
    {
        number: 'Question B2',
        question: 'This multi-part question produces a single LucidChart diagram. \nNote: you will probably need to enrich the sets of attributes and operations of the Participant class slightly. Do not modify the class diagram you drew earlier. Instead, include in your diagram (e.g. as a Note, a UML comment) a list of any extra attributes and operations you need to add. Only add things you need in order to answer this question. \n2. In the same diagram, add: \n(a) An OCL constraint, placed in an appropriate state of your diagram, describing what it means that the participant is not in a call. (That is, defining the state in terms of the object\'s properties.) \n(b) An OCL guard on the transition corresponding to the participant unmuting, to indicate that they can only do this if no other participant on the same call is unmuted. \nYour constraints may use any relevant properties from your Part A class diagram; if you need to use extra properties, make sure they are included in the Note mentioned above.\n\n',
        answers: [
            { image: '/2021/StudentA/done/B.JPG', correct: [3, 8, 10] },
            { image: '/2021/StudentB/done/B.JPG', correct: [4, 6] },
            { image: '/2021/StudentC/done/B.JPG', correct: [3, 4, 11] },
            { image: '/2021/StudentD/done/B.JPG', correct: [3, 4, 10, 12] },
            { image: '/2021/StudentE/done/B.JPG', correct: [4, 10] },
            { image: '/2021/StudentF/done/B.JPG', correct: [4] },
            { image: '/2021/StudentG/done/B.JPG', correct: [3, 1] },
            { image: '/2021/StudentH/done/B.JPG', correct: [4, 2] },
            { image: '/2021/StudentI/done/B.JPG', correct: [1, 9] },
            { image: '/2021/StudentJ/done/B.JPG', correct: [7, 4, 8] },
            { image: '/2021/StudentK/done/B.JPG', correct: [7, 4, 2] },
            { image: '/2021/StudentL/done/B.JPG', correct: [7, 8] },
            { image: '/2021/StudentM/done/B.JPG', correct: [7, 5, 6, 7] },
            { image: '/2021/StudentN/done/B.JPG', correct: [7, 4, 5, 8] },
```

```
143             { image: '/2021/StudentO/done/B.JPG', correct: [4, 10,
                    12] },
144             { image: '/2021/StudentP/done/B.JPG', correct: [1, 6] },
145             { image: '/2021/StudentQ/done/B.JPG', correct: [3] },
146             { image: '/2021/StudentR/done/B.JPG', correct: [1] }
147         ],
148         checkOptions: [
149             { id: '1', text: "OCL: an attempt, but not close enough
                    to correct for marks I'm afraid."},
150             { id: '2', text: "Guard: not done"},
151             { id: '3', text: "You were told not to add things you
                    didn't need, so you should not add a new attribute to
                     represent whether the participant is in a call: that
                     is already there in the property that is the
                    association end connecting Participant to VideoCall
                    in your class diagram."},
152             { id: '4', text: "Note that context Participant inv: is
                    not quite right: this whole state diagram is in the
                    context of Participant (so you can assume that), and
                    you are not defining an invariant of the class which
                    is what inv: means."},
153             { id: '5', text: "OCL on the unmuting transition:
                    valiant attempt but not close enough to making sense
                    for marks."},
154             { id: '6', text: "You definitely don't want to use
                    Participant.allInstances because that will make the
                    constraint depend on the states of all objects of
                    class Participant, not only those that are on the
                    same call as self!"},
155             { id: '7', text: "It isn't the role of a constraint to
                    assign a new value to an attribute."},
156             { id: '8', text: "What you want on the transition is a
                    guard in []: check you understand guards on state
                    diagram transitions."},
157             { id: '9', text: "Using oclIsInState is a bit circular!
                    What we're trying to do here is \"defining the state
                    in terms of the object's properties\"."},
158             { id: '10', text: "Since the whole diagram is about a
                    particular Participant, when you want to talk about a
                     VideoCall you have to specify which one."},
159             { id: '11', text: "self.participants doesn't make sense
                    when self is a Participant."},
160             { id: '12', text: "Good attempt at the OCL even though
                    it isn't quite right!"}
161         ]
162     }
163 ]
```

Appendix E

High-Fidelity Prototype Screens

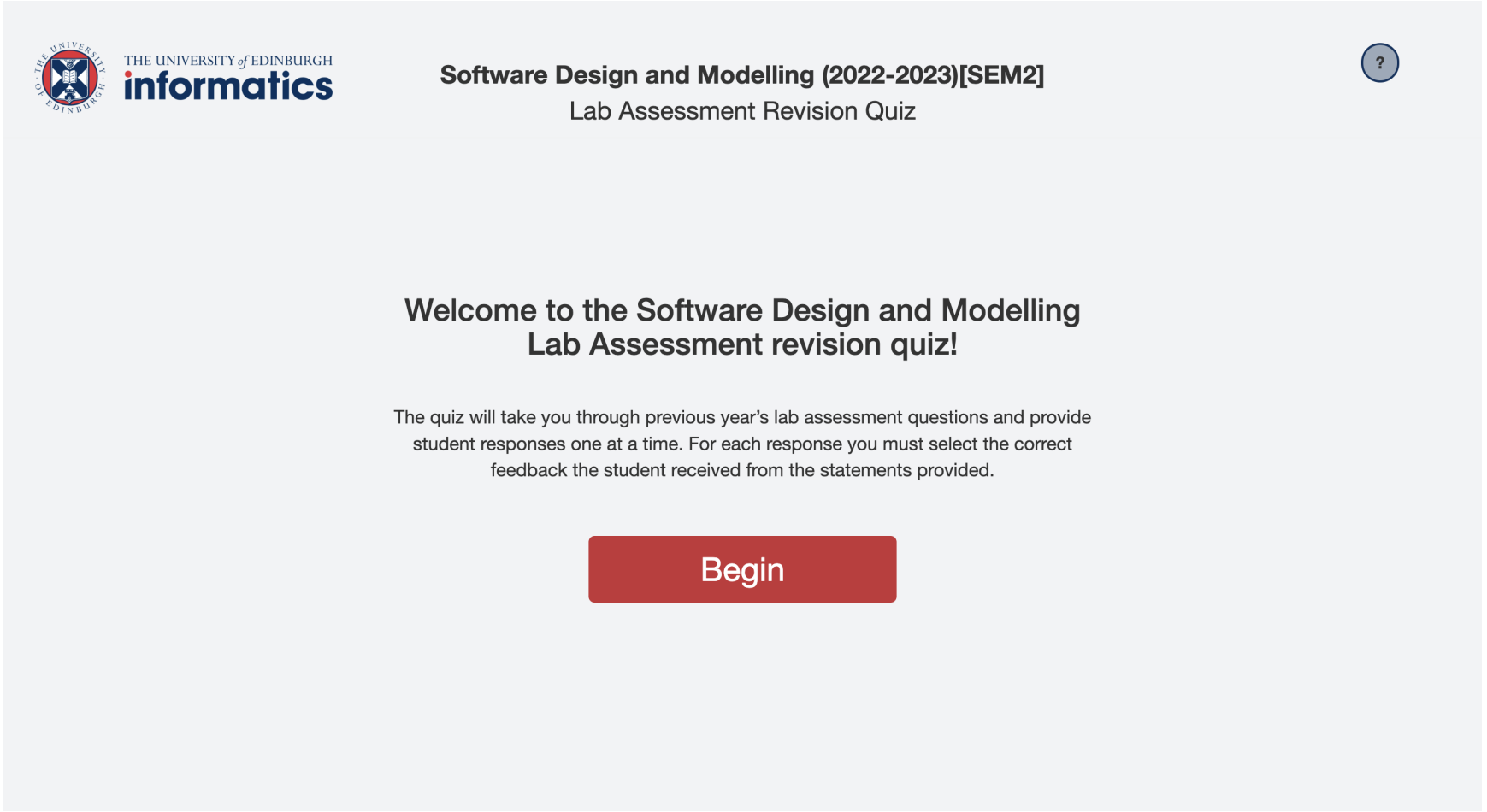


Figure E.1: High-Fidelity Prototype Start Screen

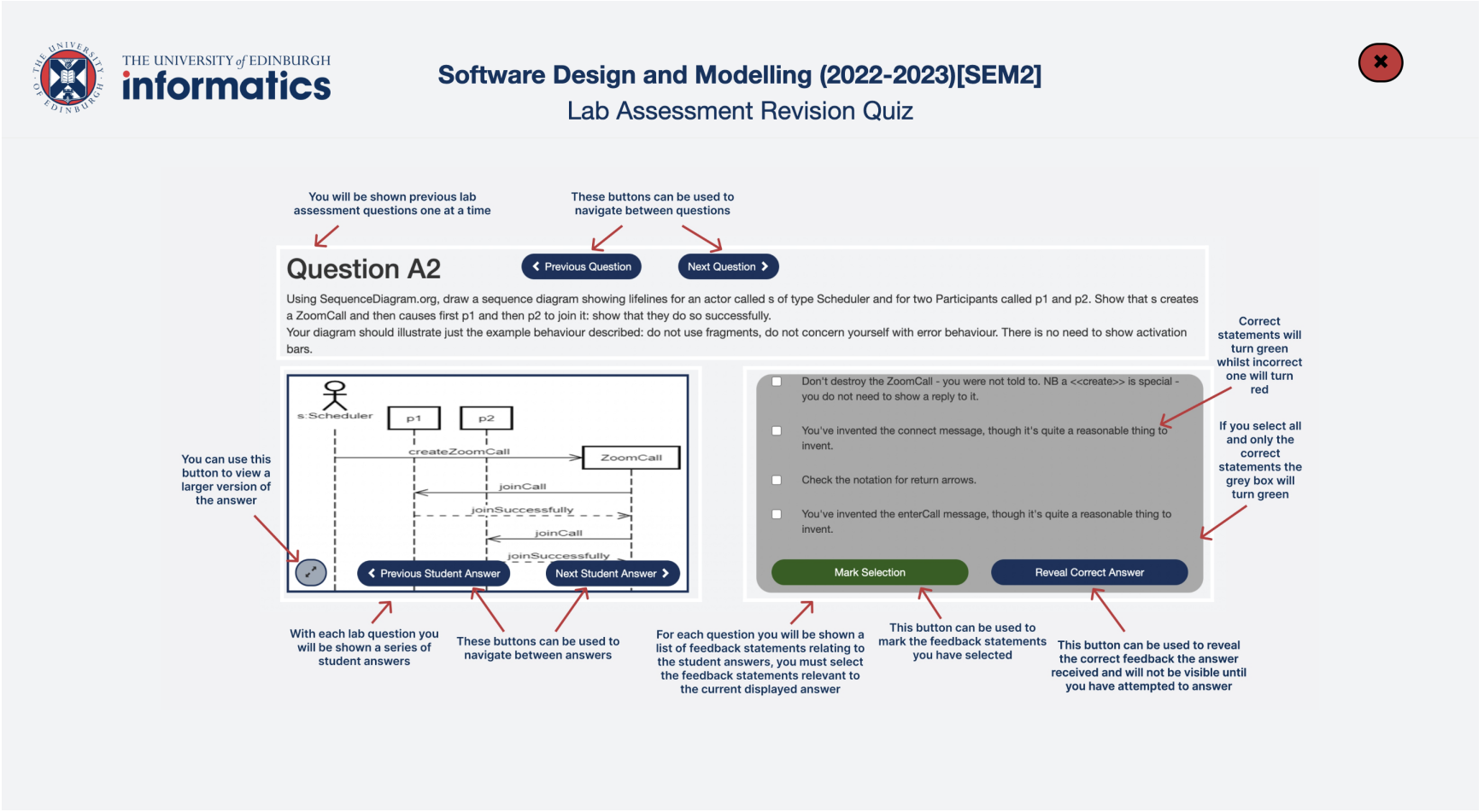


Figure E.2: High-Fidelity Prototype Help Screen

THE UNIVERSITY of EDINBURGH informatics

Software Design and Modelling (2022-2023)[SEM2]

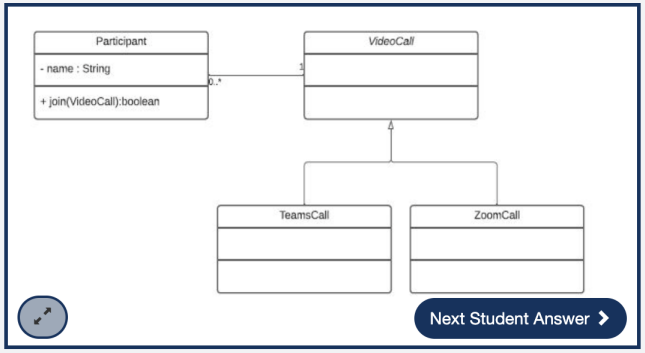
Lab Assessment Revision Quiz

?

Question A1

Next Question >

In LucidChart draw a UML class diagram showing:
(a) a class Participant with a private attribute name of type String and a public operation join taking a VideoCall as argument and returning a boolean
(b) an abstract class VideoCall
(c) concrete subclasses ZoomCall and TeamsCall of VideoCall
(d) an appropriate relationship between VideoCall, ZoomCall and TeamsCall
(e) an appropriate relationship between Participant and VideoCall, demonstrating that at any one time a given participant can be in at most one video call, while a video call may have any number of participants (including zero, say, to account for scheduled calls).



Tick the feedback statements you think this submission received (scroll for more):

- [ ] Perfect!
- [ ] You need a Generalization, shown with an unfilled triangle head, between ZoomCall, TeamsCall and VideoCall. If you use a -> head you are showing a navigable Association which is a completely different thing.
- [ ] You're showing interface realization with the dashed line, not generalization - given that VideoCall is an abstract class not an interface the latter is what you need.

Figure E.3: High-Fidelity Prototype Question Screen

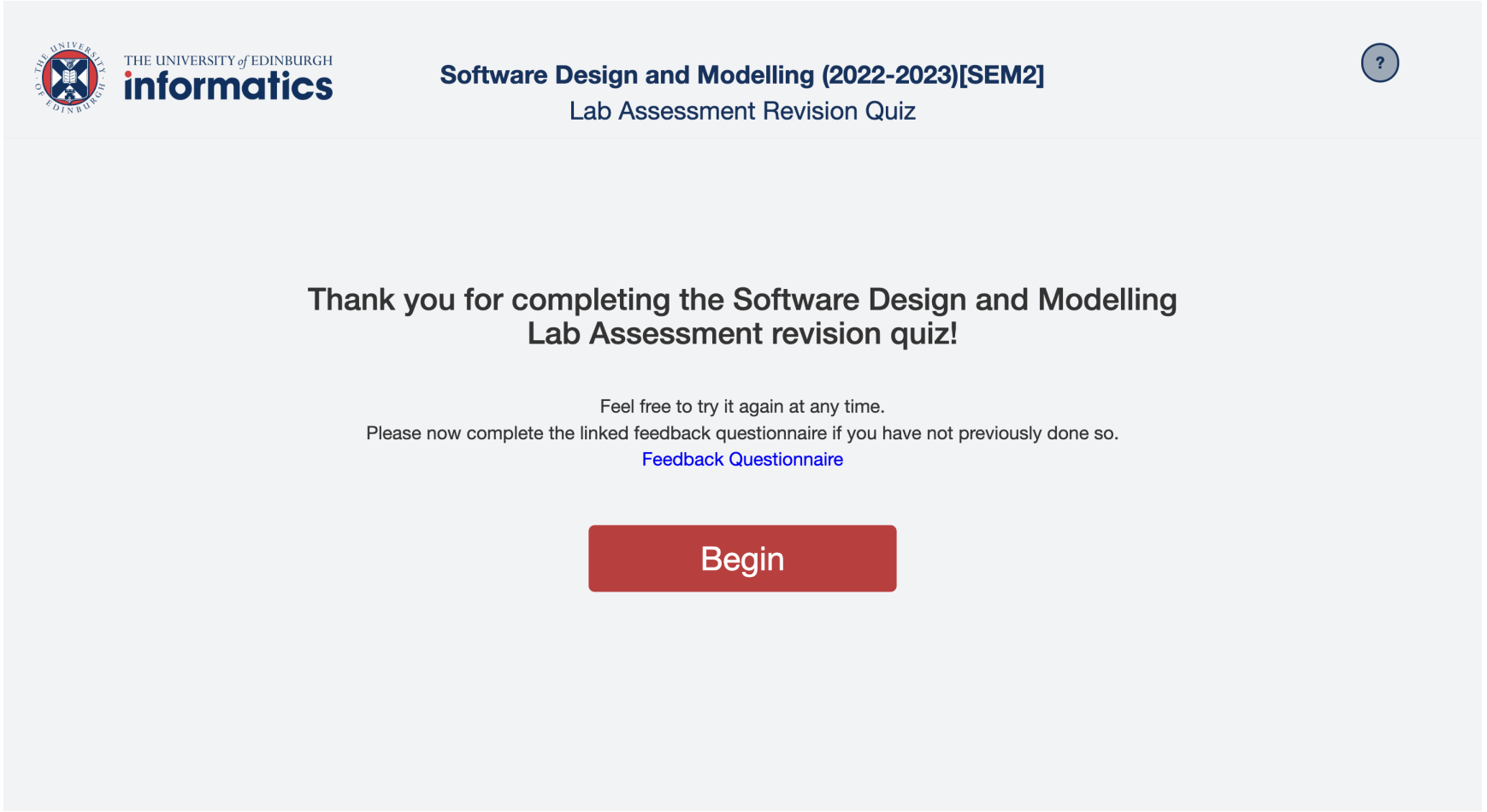


Figure E.4: High-Fidelity Prototype Final Screen

Appendix F

Questionnaire

F.1 Online Participant Information Sheet and Consent Form

Participant Information Sheet

Project title:	Creating a Tool to Help Students on the Software Design and Modelling Course Identify Problems in UML (Unified Modelling Language) Models
Principal investigator:	Perdita Stevens
Researcher collecting data:	Iona Cooper

This study was certified according to the Informatics Research Ethics Process, RT number #7139. Please take time to read the following information carefully. You should keep this page for your records.

Who are the researchers?

Iona Cooper (4th Year Undergraduate Student)

Perdita Stevens (Project Supervisor)

What is the purpose of the study?

The aim of the study is to gather information on Software Design and Modelling students experience and thoughts of the mid-term lab assessment revision tool. This will aid the researcher in improving the design for future Software Design and Modelling students.

Why have I been asked to take part?

You have been asked to take part as you take the 2022/23 Software Design and Modelling course and have used the tool.

Do I have to take part?

No – participation in this study is entirely up to you. You can withdraw from the study at any time, without giving a reason. Your rights will not be affected. If you wish to withdraw, contact the PI. We will stop using your data in any publications or presentations submitted after you have withdrawn consent. However, we will keep copies of your original consent, and of your withdrawal request.

What will happen if I decide to take part?

Taking part means you will complete a short survey regarding your experience of the Software Design and Modelling revision tool. The questionnaire will take around 5/10 minutes.

Data gathered will be anonymised before use.

Are there any risks associated with taking part?

There are no significant risks associated with participation.

Are there any benefits associated with taking part?

The tool should improve your understanding of Software Design and Modelling course material and play a role in your revision for the mid-term lab assessment.

What will happen to the results of this study?

The results of this study may be summarised in published articles, reports and presentations. Quotes or key findings will be anonymized: We will remove any information that could, in our assessment, allow anyone to identify you. With your consent, information can also be used for future research. Your data may be archived for a maximum of 1 year. All potentially identifiable data will be deleted within this timeframe if it has not already been deleted as part of anonymization.

Data protection and confidentiality.

Your data will be processed in accordance with Data Protection Law. All information collected about you will be kept strictly confidential. Your data will be referred to by a unique participant number rather than by name. Your data will only be viewed by the researcher/research.

All electronic data will be stored on a password-protected encrypted computer, on the School of Informatics' secure file servers, or on the University's secure encrypted cloud storage services (DataShare, ownCloud, or Sharepoint) and all paper records will be stored in a locked filing cabinet in the PI's office. Your consent information will be kept separately from your responses in order to minimise risk.

What are my data protection rights?

The University of Edinburgh is a Data Controller for the information you provide. You have the right to access information held about you. Your right of access can be

exercised in accordance Data Protection Law. You also have other rights including rights of correction, erasure and objection. For more details, including the right to lodge a complaint with the Information Commissioner's Office, please visit www.ico.org.uk. Questions, comments and requests about your personal data can also be sent to the University Data Protection Officer at dpo@ed.ac.uk.
For general information about how we use your data, go to: edin.ac/privacy-research

Who can I contact?

If you have any further questions about the study, please contact the lead researcher, Iona Cooper at s1940351@ed.ac.uk.
If you wish to make a complaint about the study, please contact inf-ethics@inf.ed.ac.uk. When you contact us, please provide the study title and detail the nature of your complaint.

Updated information.

If the research project changes in any way, an updated Participant Information Sheet will be made available on http://web.inf.ed.ac.uk/infweb/research/study-updates.

Consent

By proceeding with the study, I agree to all of the following statements:

- I have read and understood the above information.
- I understand that my participation is voluntary, and I can withdraw at any time.
- I consent to my anonymised data being used in academic publications and presentations.
- I allow my data to be used in future ethically approved research.
  [Button here named "I agree" or "take me to the survey"]

F.2 Open-Ended Questions Answer Data

6. If for the above question (5) you disagree, please explain why.

I didn't realise that I can scroll down in the grey box, so I wouldn't be able to find the reveal answer button unless I asked for help

I don't quite... disagree, the tool was intuitive to use but there were a number of times where answers were effectively duplicates of one another (further extrapolated on in improvements). Additionally, the first time reading through a question took a long time as all possible marker options had to be read and understood.

7. Was there anything you particularly liked about the tool?

It would was very interesting to see the marking to prompt me on what areas i am more and less confident in

I liked the colour scheme of changing the text red/green. I like how this is a permanent change so you can remember which ones you have already guessed.

I liked the aesthetic of the quiz, very professional looking and consistent.

Expanding the image Ability to move the image around

I liked the maximise functionality and the ease of navigation i.e. navigate forward and backwards seamlessly between pages. I also liked the coloured box's and text to resemble correct or incorrect answers.

I can train my knowledge of UML and check my understanding by finding errors in other people's answers and correcting them.

Lots of examples provided, UI is easy on the eyes and intuitive. I like that there's an option to enlarge the image

I liked the design, how you could increase the size of the diagrams and the colours were helpful.

showing the correct diagram at some point nice interface, quick and easy to use

I liked the intuitiveness and how we were able to see past examples of students' answers (likely with mistakes we ourselves would make) and feedback on the answers

I liked the format, matching the feedback to the answers helped understand common pitfalls in writing diagrams.

Easy to use. Useful in improving knowledge

8. Are there any improvements you would like to see in the tool?

Tool didn't remember my previous responses to questions if I moved forward and then back to a previous question. Wasn't intuitively obvious that I could scroll the question box up and down.

Possible feature of remaining correct answer when you click mark answer (as commonly i i would get 2/3 correct but not know how many more i was looking for

it would be good if instead of just selecting the box beside the feedback- you could also click on the text itself. Additionally, the text on the 'Next Student Answer' button disappears when clicked which made me think there were no more example answers when there was. In some questions the enlarge window button did not actually make it larger- it just made it the same size. It would be nice to have something that says Example x of y. So for example if im on the third example for A1 out of 10 it would say 'Example 3 of 10'. This could also be applied for the Questions.

The "Mark Selection" option was not obvious, and I didn't know to scroll until I started thinking why am I getting no feedback (I thought I would be getting feedback at the end). Perhaps it should be more obvious that there are more options. The separation between "Next Question" and "Next Answer" buttons were unclear, I wasn't sure which to press first.. There was a lot of information in the pop up "i" button so I found it hard to navigate.

I should be able to select an option and have it select, not solely just select the checkbox It might be nice to score, count up my correct/incorrect responses, and show that to me at the end The order of student responses could be randomised, that would aid use in revision

I enjoyed using the tool but I think the mark selection and reveal correct answer buttons should be outside of the answers box because then they would be easier to see.

It would be useful to have a feedback button or a link for every single question (and every image in that question) so that the user can report issues with the answers. In some of the questions for the sequence diagrams, the expand image button still does not show the whole image. Some of the questions mark correct answers as incorrect even though the selected feedback applies to them.

The feedback that was given was not accurate for every diagram and sometimes it was contradictory. There should be more consistency so that the tool is actually useful and reflects the actual way in which the lab assessment will be marked.

When getting the answer correct: the whole selection box turns a bright green which is a bit too much personally (I might just be sensitive to colours). An alternative would be to have a text/tick confirmation in green appear in place of the "mark selection button", after the selection is made Some examples have wrong/incomplete feedback, as highlighted by Perdita. This could have been caused by errors in the marking itself, so not necessarily an issue with how the tool was made. An idea would be to have a feedback/bug report button of sorts so people can signal these issues and they can be corrected.

I might like it if when you select reveal answer, there was some way to compare it to the one you had before, like displaying the incorrect ones in red still for instance

expanded to more scenarios and less incorrect student responses maybe see statistics after completion

Maybe at the start, we could be asked to do the question ourselves or asked to think about what feedback we would give before doing the multiple choice to get us to think more

bigger radio buttons, more padding everywhere, generally nicer styling

There were multiple cases where different options that applied to the current student question (e.g. QB1 “did not use method calls, make sure to have brackets”) were either too similar - multiple answers said almost the same thing, or applied, but did not get matched as “correct”. I assume that this is due to the marking feedback for those questions not being completely comprehensive on all errors, merely pointing out the most eggregious ones, but to further improve, I would certainly try to aggregate similar marker comments together and double check whether they apply to diagrams, even if they are not in the marker feedback for that diagram. This is mostly a consistency issue.

Double checking of answers and feedback. One answer was marked as perfect despite it having the wrong arrow type

9. Any other comments?

Personally, I found the amount of possible answers a bit overwhelming in that there were too many to read through per question. To combat this I’d suggest limiting the answers more between different student answers.

Really nice tool. Best of luck with the rest of your dissertation, from a fellow 4th year :)

nice work

All the best!

Thank you for the tool! Admittedly I said I was less confident in the midterm, but I think that’s more to do with Dunning-Kruger than anything else :)

F.3 Likert Scale Questions Answer Data

ID	1. My knowledge of UML models has improved.	2. I feel more confident for the mid-term lab assessment.	3. I would prefer to use the tool to revise than other revision methods. (e.g. readings, rewatching lectures)	4. I would use the tool again in my revision.	5. I found the tool easy to use.
2	Agree	Agree	Neutral	Strongly agree	Strongly agree
3	Strongly agree	Agree	Strongly agree	Strongly agree	Agree
4	Agree	Agree	Agree	Agree	Agree
5	Agree	Agree	Agree	Agree	Agree
6	Agree	Agree	Agree	Strongly agree	Agree
7	Agree	Agree	Agree	Agree	Agree
8	Agree	Agree	Neutral	Agree	Agree
9	Strongly agree	Strongly agree	Agree	Strongly agree	Neutral
10	Agree	Agree	Strongly agree	Strongly agree	Agree
11	Agree	Strongly agree	Agree	Agree	Strongly agree
12	Agree	Agree	Neutral	Agree	Strongly agree
13	Agree	Strongly agree	Agree	Agree	Agree
14	Strongly agree	Strongly agree	Strongly agree	Strongly agree	Strongly agree
15	Agree	Disagree	Neutral	Agree	Neutral
16	Agree	Agree	Strongly agree	Strongly agree	Strongly agree

Figure F.1: Likert Scale Questions Answer Data

Appendix G

Suggested Improvements Evaluation

- **Issues with consistency in tool content (mentioned by 5 students).**

  Solution: Whilst the project supervisor and myself did attempt to clean the data and note as many consistency issues as possible, there are still some that were missed. Many students suggested that to combat this a bug/error reporting button be implemented for each answer in the tool so that if students found inconsistencies they could be reported. This is a favorable suggestion and would definitely be taken into consideration for future development of the tool.

- **No intuitive scrolling, mark feedback statement selection button not visible until scrolled (mentioned by 3 students).**

  Justification and Solution: Whilst this has already been discussed along with the student solution (placing mark and reveal correct statements outside the feedback statement box) it is worth taking into consideration for future development of the tool having been mentioned by 3 students. Although it may increase the complexity of the page, it may in turn improve usability. Therefore, for future work I would suggest focusing on this aspect in any user studies.

- **Can only click on checkbox associated with a feedback statement rather than the statement text itself (mentioned by 3 students).**

  Solution: This was a design feature that as a creator rather than user of the tool I overlooked. Therefore, I would suggest the implementation of this in future studies to aid tool usability.

- **No scoring for number of answers achieved correct feedback for at the end of the tool (mentioned by 2 students).**

  Justification: This was mentioned previously in the evaluation of the low-fidelity prototype with the project supervisor when they wanted marks for questions and answers to be taken out of the tool. Therefore, it would not make sense to add them back in and, to an extent, gamify the tool, possibly taking students' attention away from the revision aspect and leading them to focus more in 'winning' the game/achieving the highest score possible.

- **Enlarged student answer image still not big enough (mentioned by 2 students).**

  Solution: Again this was an oversight on my part, considering the tool as a creator rather than a user. Therefore, for future implementations I would suggest the enlarged student answer image was not only draggable but also resizable.

- **No state continuity, i.e. tool does not remember state of feedback box/statements between questions or when the correct answer is revealed. (mentioned by 2 students).**

  Solution: These are 2 separate suggestions with similar ideas. In terms of a solution/future developments it would be a good idea to investigate this in a user study - do students want their incorrect answers still in red when the correct answer is revealed and do they want their attempt of an answer to be in that state if they move on answer/question and come back to it.

- **No answer order randomization, same between each use of tool (mentioned by 1 student).**

  Justification/Solution: This suggestion was considered in the implementation of the tool, however, not being essential for the main interface, there was not enough time for it to be implemented. Therefore, some kind of algorithm determining a the order of the questions would be a good addition to the tool in future.

- **When a question is marked incorrect but all correct statements selected hard to know how many more to look for (mentioned by 1 student).**

  Solution: This suggestion was on the original list of features to implement but again time ran out before it could be implemented. Therefore, it would definitely be a suggestion for future developments to add some kind of hint button detailing the number of feedback statements applicable to the current student answer.

- **There is no way to tell how many questions/answers for the current question, are left to go through and so there's no way to tell how far you have progressed/is left to progress through the tool (mentioned by 1 student).**

  Solution: As with the last issue this suggestion was on the original list of features to implement but again time ran out before it could be implemented. Therefore, it would definitely be a suggestion for future development to add the number of questions/answers left to the next buttons.

- **The help screen contains a lot of information and so is hard to navigate (mentioned by 1 student).**

  Solution: Again, due to time constraints, the help page was not as polished as I would have liked. However, again there had to be priorities and as there was to be a presentation to describe the use of the tool to students, the help screen shouldn't have had to be used often by students if at all. Although it is definitely a future development to make the help screen interactive, and more aesthetic and informative.

- **There is "*more padding everywhere, generally nicer styling*" needed. (mentioned by 1 student).**

  Justification: This comment seems to come down to more personal opinion. As someone new to working with HTML and Bootstrap there will definitely be room for improvement in the styling for those more experienced. However, most students as well as myself and the project supervisor seemed content with the styling of the page and so as not a vital or significant change, it was not put down as a key extension for future work.

- **The button format when clicked is confusing as the text turns black making the user unsure whether it is still functional. (mentioned by 1 student).**

  Justification: The comments for the prior issue also stand for this comment. The styling of the page was like by most of the individuals who used it and, whilst there is probably room to make it slightly cleaner, it is not significant enough issue to be listed for future work.

- **The 'Next Question' and 'Next Answer' buttons are too similar and make functionality confusing. (mentioned by 1 student).**

  Solution: This comment is more an issue with understanding of the functionality of the user interface. This is an issue that would be solved by a more thorough initial presentation and a better help button, both of which are listed for future work.

- **When a student selects all correct feedback statements and then marks their choice the box turns green, this is too much. (mentioned by 1 student).**

  Justification: This comment again is more personal opinion and whilst it would be recommended that anyone conducting future work on this project evaluated all of these issues in a user study, as it has only been mentioned by one student currently, it was not mentioned in key future extensions as it was not a priority.

- **There could be more questions/scenarios covered by the tool. (mentioned by 1 student).**

  Solution: This comment has already been covered in the recommended extensions for future work as it was picked up that the lack of question types could put students off using it compared to other revision methods.

- **Students do not have a chance to attempt the question before an answer is displayed. (mentioned by 1 student).**

  Justification: Whilst this is a relevant point, the tool is designed to help them spot errors in UML diagrams rather than to test their ability to create diagrams. Therefore, doing this would change the tool's purpose. This is rather something students should be able to decide from themselves (i.e. they are told the tool uses old lab assessment questions so if they would like to try them before seeing other student answers they can do this in their own time before using the tool).

Appendix H

Supervisor Tool Update Data Instructions

SDM Mid-Term Lab Assessment Revision Tool Update Instructions

1. During marking collate a document/text file containing a numbered list of all applicable feedback statements for each question.

2. Assign each student answer, to be included in the tool, the number(s) of the feedback statement(s) they received.

3. Navigate to the script.js file in the tool repository.

4. Navigate to line 237 or to the ‘questions’ constant.

5. Navigate to the last square bracket of the ‘questions’ constant.

6. Add each question in the following format (use ‘\n’ for a new line):

```
,

{
        number: ‘<question number/title here>’,
        question: ‘<question description/content here>\n\n',
        answers: [
                { image: '<path to student answer image file here>’, correct: [<comma separated
                list of feedback statement numbers here>] },
                { image: '<path to student answer image file here>’, correct: [<comma separated
                list of feedback statement numbers here>] },
                { image: '<path to student answer image file here>’, correct: [<comma separated
                list of feedback statement numbers here>] }
        ],
        checkOptions: [
                { id: '<feedback statement number here>', text: "<feedback statement here>"},
                { id: '<feedback statement number here>', text: "<feedback statement here>"},
                { id: '<feedback statement number here>', text: "<feedback statement here>"}
        ]
}
```

7. Create a new folder for/directly add all student answer images in the main repository.