Staidr:

Bridging Online, Offline, and Hybrid Learning Through Collaborative Methodologies

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CONTENTS

LIST OF FIGURES

LIST OF TABLES

Acronym	Definition
MULE IDE	Maynooth University Learning Environment Integrated Development Environment
CLS	Collaborative Learning Session
MOOC	Massive Open Online Courses
PAL	Peer Assisted Learning
CS1	Introductory Computer Science Module
CA	Continuous Assessment
MERN	MongoDB, ExpressJS, React, and NodeJS
DOM	Document Object Model
MVP	Minimum Viable Product
CRUD	Create, Read, Update, and Delete
SSE	Server Sent Events
XMPP	Extensible Messaging and Presence Protocol
FGCS	First-generation College Students
NFGCS	Non-first Generation College Students
G1	Group 1
G2	Group 2

ABSTRACT

Staidr was developed as a tool to enable students to collaborate effectively in online, offline and hybrid environments. The project has been developed over the last two years, and this thesis details the journey from initial research through the development of the platform, the resulting validation of this platform and the underlying methodology.

Three studies were conducted throughout this project: a pilot study to fully understand the effectiveness of the pedagogical methodology, followed by a more accelerated study to introduce the online platform. We encapsulated our evaluation by performing a final year-long study examining the effects of our application on a university class throughout two semesters.

Overall, both the methodology and platform have been well received by educators and students alike. Our feedback indicated a clear use case for such a platform, and further developments will only improve its significance.

PUBLICATIONS

[1] S. O'Neill and A. Mooney. "Developing a Collaborative Learning Application to Support Effective Student Collaboration in Hybrid Learning Environments". In: *EDULEARN23 Proceedings, pp. 4931-4936.* (2023).

[2] S. O'Neill and A. Mooney. "Introducing a collaborative learning strategy in a hybrid and traditional laboratory for undergraduate computer science students." In: *9th International Conference on Higher Education Advances (HEAd'23)* (2023).

[3] S. O'Neill and A. Mooney. "Investigating the Impact of Collaborative Learning on Undergraduate Computer Science Students". In: *EDULEARN23 Proceedings, pp. 4986-4992.* (2023).

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DECLARATION

I confirm that this is my own work and the use of all material from other sources has been properly cited and fully acknowledged.

Co. Kildare, Ireland, October 2023

Sam O'Neill

2023

Part I

INTRODUCTION AND BACKGROUND MATERIAL

1 INTRODUCTION

1.1 INTRODUCTION

The direction of education has been notably influenced by advancements in technology and evolving pedagogical practices. One particularly prominent area, especially in recent years, is collaborative learning, especially in the context of hybrid & remote environments. This thesis is dedicated to exploring the development of the Staidr App, a tool designed to enhance collaborative learning in the ever-evolving educational landscape.

In this chapter, we present the research methodology we have used, providing a glimpse into the approach we have taken to attempt to answer our research questions and how we expect to meet our research objectives. Following that, we will delve into the evolution and current state of hybrid and remote learning.Collaborative learning, central to our study, will be thoroughly examined through the lens of past and current academic practices, dissecting the elements that contribute to its efficacy. Following this we will discuss the background of this project and how it evolved within Maynooth University, leading to the development of the Staidr App. Then we outline our research objectives and research questions. Finally, we offer an overview of the forthcoming chapters.

1.2 RESEARCH METHOD

Our research methodology involves several distinct stages, each instrumental in ensuring the comprehensiveness and rigour of our study. We began with a review of existing literature, aiming to gain a comprehensive understanding of collaborative learning research. This review spanned various repositories, encompassing the years from 1999 to 2023. Next, we reviewed the possible types of application and development environment, a crucial step in aligning our study with the practicalities of contemporary learning modes. This involved a thorough assessment of different development technology options and application types, such as web, mobile, and desktop frameworks. The intention was to ascertain the most effective channel through which participants could engage in collaborative learning. This strategic analysis guided the subsequent phases of our methodology.

We then turned our attention to defining our pedagogical methods, a critical aspect that underpins the validity of our findings. A pilot study was conducted to refine our methodological approach, effectively serving as a trial run to calibrate our methodology. This pilot study allowed us to fine-tune our methods based on real-world feedback and data, ensuring the robustness of our approach. To fully explore our research questions, a three-part study structure was implemented. The initial pilot study formed the foundation for methodological adjustments, instilling methodological confidence before delving deeper. In subsequent studies, we pursued a dual approach; some participants engaged in a simulated remote environment, while others worked in a fully offline context. This setup enabled us to compare outcomes effectively, discerning the nuances of collaborative learning in both scenarios. As our study progressed, the Staidr App evolved as well, incorporating more features and user experience improvements based on insights garnered from earlier phases. These insights, collectively amassed from a series of well-defined phases, offered a comprehensive understanding of the impact of collaborative and hybrid learning on study group effectiveness. The flow of this research method is illustrated in Figure 1.1.

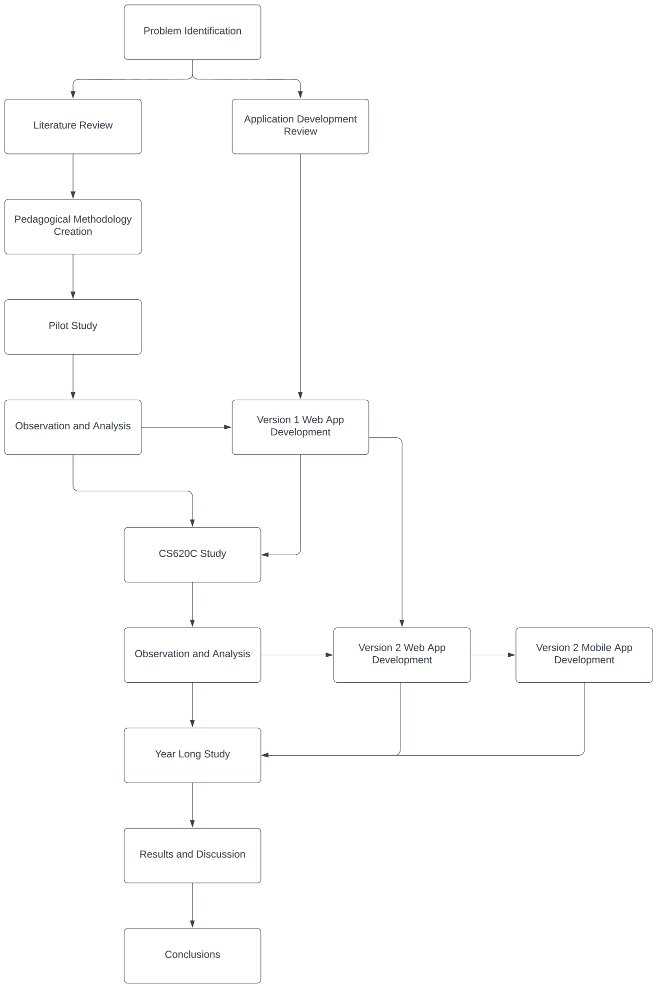

Figure 1.1: Research Methodology Flow

1.3 REMOTE & HYBRID LEARNING

The history of remote and hybrid learning can be traced back to the very beginning of the Internet. The Internet was originally conceived as a platform for researchers to share resources and over the past 50 years, the Internet rapidly evolved into a global communication hub, reshaping numerous aspects of education. With digital connectivity as its cornerstone, the rise of online learning was instrumental in laying the groundwork for remote and hybrid education, subsequently solidifying their place among traditional education. During the COVID-19 pandemic, remote learning had sharp increase in traction within Ireland's educational landscape, a 60% increase in the use of remote learning in higher education was reported by Ireland's Department of Further Education and Higher EducationDepartment of Education and the Department of Further and Higher Education, [12]. Previously remote learning relegated to a niche corner of education many institutions began integrating it as a primary option. The pandemic, acted as a catalyst, bringing remote learning to the forefront of educational discourse and practice. This crisis showcased the potential of remote learning when supported by necessary resources, demonstrating the adaptability and resilience of educators and students alike in embracing alternative modes of instruction. Post-pandemic, the educational landscape evolved, with educators embracing aspects of online learning and remote instruction as integral components of modern pedagogy. This shift extended beyond mere crisis management, integrating online lectures, virtual assessments, and other digital learning tools into curricula. This introduction of hybrid learning, blending the traditional classroom with online elements, further accentuated the transformation, presenting new avenues to encourage engagement and accessibility. The result of these diverse educational methodologies demonstrates a positive development of the learning experience, with the flexibility of remote and hybrid learning offering prospects to tailor education to varied preferences and circumstances.

1.4 MAJOR FACTORS IN COLLABORATIVE LEARNING

Collaborative learning, a method rooted in active learning, prompts students' engagement through collaboration to decipher problems or gain a greater understanding of course material collectively Smith and MacGregor [38] Dillenbourg [14]. Within this collaborative landscape, students combine their skills to navigate more challenging aspects of material, thereby uncovering gaps in their collective understanding and assisting one another in bridging these gaps. This type of work encompasses the essence of the saying, "Two heads are better than one." Traditional lectures often present students with a passive role in information absorption, while note-taking triggers active comprehension. Collaborative learning, however, advances this, bringing a more high-level grasp of subject matter as students are forced to articulate and share their comprehension with peers, thereby reinforcing their own grasp of the subject. In the context of this project, our focus was on utilising the power of collaborative learning to leverage class material for collective problem-solving, particularly in the realm of practical coding exercises.

When we examine the underlying components that encourage effective collaborative learning, we encounter crucial factors that shape the success of this approach Stacey [40] Vygotsky [45]. For instance, the size of the collaborative group and their collective understanding of the topic significantly influence how the group functions. Allocating an appropriate amount of time for tasks is also vitally important, as it enables comprehensive collaboration. Moreover, the learning environment itself plays a pivotal role. Creating an atmosphere that encourages open sharing of ideas and equal participation is essential, as it profoundly impacts the effectiveness of collaborative learning.Smith and MacGregor [38] Additionally, how people interact is also a significant aspect. Whether the interaction occurs simultaneously or at different times, it has a direct impact on the overall learning experience and the engagement of the group.

1.5 UNDERGRADUATE WORK

The origins of this current project were founded in a final-year undergraduate project in 2021. However, this work evolved into a thorough investigation into the effectiveness of collaborative learning across online, in-person, and hybrid formats. The final year project emerged as a solution to the sudden shift to online learning and the lack of dedicated online study spaces for final-year science students at Maynooth University, aiming to create an online platform for resource sharing and collaborative engagement.

Among the changing landscape of online education, the need to provide students with such a resource became evident. The project's core objective involved creating a Minimum Viable Product (MVP) of a collaborative learning app, which was then tested with small focus groups. The insights gained revealed two key findings: students expressed a desire for a platform like this, and the app's focus should be on assisting with collaborative assignments and projects rather than just accompanying classroom activities.

After completing this initial project, it was decided to explore this research area further. Recognising the potential for broader implications and a deeper understanding of collaborative learning, the transition from an undergraduate initiative to a comprehensive research project marked the beginning of this thesis. All further work described in this thesis was completed as part of the postgraduate program. While great insights and potential were discovered from the undergraduate work the methodology and subsequent software applications created required the timeline and skills developed for the postgraduate degree.

1.6 KEY TOPICS USED THROUGHOUT THESIS

1.6.1 MULE IDE

The MULE IDE, an acronym for Maynooth University Learning Environment Integrated Development Environment, is a standout product of diligent research from the Maynooth University Computer Science Department Culligan [10] Culligan and Casey [11]. MULE provides a tailored development environment, where lab questions and test cases can be easily set by administrators. Its flexible features allow specific questions to be displayed or hidden, this functionality is greatly utilised in this project as we want some questions to be available to students leading up to their weekly laboratory and some to only be accessible within lab time. Like most IDEs, Students can then access the lab questions and compile and run their code. However, what sets MULE apart is its 'Evaluate' feature, enabling students to run their code against predefined test cases and get a tangible score out of 100. Demonstrating its adaptability, MULE supports a wide range of languages, from Java and Python to Prolog and others.

1.6.2 MODULE CODES

Throughout this study, we make reference to three separate computer science modules taught at Maynooth University. Our three studies took place within these modules, with our third study encompassing two modules over one academic year. We chose these modules as each utilises the same methodology of laboratory assignments, which was the testing ground for our research. Each module has a set selection of assignments hosted on the MULE IDE (see Section 1.6.1)

- **CS161 (Introduction to Computer Science I)**: This module takes place in the first semester of the academic year and is offered to first-year undergraduate students. At Maynooth University, this module is an option for many degrees, both within the Science faculty and Arts faculty and with numbers approaching 600 taking this module. This module focuses on core programming skills and foundational object-oriented topics.
- **CS162 (Introduction to computer science II)**: This module takes place in the second semester of the academic year and is a continuation of the CS161 module. This module builds upon the skills learned in CS161 and explores the more abstract areas of object-oriented programming.

- **CS620C (Structured programming)**: This module is a three-week accelerated introduction to programming module. It takes place each year in the month leading up to Semester 1, typically in early September. This module encompasses the same practical material as both CS161 and CS162 combined. This module is part of a skill conversion course, due to this, all students have completed a prior bachelors degree and many participants have been working in various industries for a number of years.

1.6.3 COLLABORATIVE LEARNING SESSION

Our CLS or Collaborative Learning Session is the name given to the time set aside to perform our experiment within the pre-existing learning activities of our studies. All of our sessions follow a similar format either in an offline or a simulated online scenario. The structure of the session is further discussed in Section 3.2

1.6.4 MERN

MERN stands for MongoDB, Express.js, React, and Node.js. In this project, the "R" in MERN encapsulates both ReactJS, used for web app development, and React Native, utilised for mobile app creation. We opted for the MERN tech stack because its consistent use of JavaScript facilitates development across multiple platforms, offering a more streamlined and efficient process than alternatives like the LAMP [1] stack.

1.7 ETHICAL APPROVAL

Before any data used in this project was collected, we sought and received approval from the Maynooth University Research Ethics Committee (Ethics Review ID: 2471954). To receive this approval we developed an Information Sheet and included a consent form within the initial survey given to each

1 https://en.wikipedia.org/wiki/LAMP_(software_bundle)

participant of our studies as well as our weekly follow up surveys, all of which can be found in Appendices C, D and E.

1.8 RESEARCH OBJECTIVES

- **Methodology Creation**: The first objective of this research project is to design and test a pedagogical methodology that could introduce collaborative learning within pre-existing learning activities. This methodology should be implemented in tandem with the application developed alongside the methodology and should support and evaluate students learning by increasing the amount of active participation in a task.
- **Application Development** : For our second objective we aim to design and construct a functional online platform to support collaborative learning.

1.9 RESEARCH QUESTIONS

- **Does engaging in a study group foster a greater interest in a subject?**:

  We will explore how taking part in a study group influences students interest in a subject and consequently do study groups help improve engagement with class material.
- **Does the use of an online study group help improve a student's grades in a subject?** :

  We will investigate if utilising collaborative learning in an online context has an impact on students academic success.
- **What effect does the demographic of user have on their experience with the platform, e.g. gender, race, college course, leaving cert results, first generation college students?**:

> We will examine current literature and investigate whether a students demographic has an impact on their utilisation of an online learning platform and engaging in online collaborative learning.

1.10 THESIS OVERVIEW

Chapter one introduces the thesis and describes the research methodology that will be present within the subsequent chapters. It also introduces the paper's main themes and the project's history.

Chapter two provides an overview of the literature studied throughout this project. It also dives into further detail on the work published throughout this project and examines how collaborative learning has been studied over the last two decades with a core focus on our research questions.

Chapter three describes the development of our pedagogical strategy and details how we conducted our studies and the protocols we followed. We also discuss our method of data collection.

Chapter four details the creation of our software, we discuss the development methodology used and do an in-depth look at our applications functionality.

Chapter five discusses our first case study in which we conducted a pilot study to test our pedagogical methodology. Our findings are presented with analysis of two different types of surveys to convey how effective our method is at encouraging collaborative learning.

Chapter six examines our second study which took place within an accelerated summer university course. We detail the challenges and success of our first deployment of the web application and detail our findings in our participants experience using it.

Chapter seven provides an overview of our longest study, in which we follow two groups of students and measure their experience with a offline and online version of the methodology. We then present our findings in a comparative analysis between both groups.

Chapter eight concludes this thesis providing a discussion on the outcome of each of our studies. Furthermore we discuss the published work completed alongside this research project and future work planned on this topic.

2

LITERATURE REVIEW

2.1 INTRODUCTION

At the beginning of this project, we needed to hone in on what features of collaborative learning we wanted to explore. As stated in Chapter 1, this project followed on from a final year capstone project. The scope of that project uncovered that collaborative learning could be a viable and useful option for third-level students, but a properly documented research endeavour would be required to uncover why or how this can be implemented.

This chapter presents our findings into research completed in the field of collaborative learning in a remote or hybrid environment through the use of a literature review.

2.2 RESEARCH QUESTIONS

The initial step in conducting a literature review involves the creation of research questions that will guide the investigation. In our study, we considered the aspects of collaborative learning that warrant exploration and the specific dimensions of engagement, academic performance, and demographic factors that promise valuable insights. We have outlined our research questions as follows:

- Does engaging in a study group foster a greater interest in a subject?
- Does the use of an online study group help improve a student's grades in a subject?

- What effect does the demographic of user have on their experience with the platform, e.g. gender, race, college course, leaving cert results, first generation college students?

2.3 PAPERS

Within this section we detail the papers selected for our literature review. Table 2.3 organises these papers into reference key, year published, publishing location and topic area.

Table 2.1: Overview of papers

Reference	**Year**	**Publishing Location**	**Topic Area**
Alem and Kravis [1]	2005	Journal	Education, Collaborative learning, Distance learning, E-learning
Arendale and Hane [2]	2014	Journal	Peer Assisted learning, Survey
Babić and Kolar [3]	2021	Journal	Team Learning, Cooperative Learning, Collaborative Learning
Brindley and Walti [4]	2009	Journal	Distance education, online learning, e-learning, collaborative learning
Bruffee [5]	1999	Book	Education, Collaborative Learning
Burrowes [6]	2003	Journal	Collaborative Learning, Education

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Table 2.1 – continued from previous page

Reference	**Year**	**Publishing Location**	**Topic Area**
Chen and Chen [7]	2015	Journal	Cooperative learning, Pedagogical issues, Teaching/learning strategies
Chiong and Jovanovic [8]	2012	Journal	Collaborative Learning, Online Group Work, Evolutionary Game Theory
Clarke and Potvin [9]	2021	Journal	Software engineering education, Collaborative learning
Desai, Ramasamy, and Kiper [13]	2020	Journal	Education, Collaborative Learning, Student Assessment, Learning Management Systems
Dolmans and Schmidt [15]	2006	Journal	Collaborative Learning, Group Learning, Problem-based Learning
Harmon and Erskine [16]	2023	Web Page	Education, Report
Hegarty-Kelly and Mooney [17]	2021	Journal	Automated Assessment, Computer Science Education, CS1, Coding
Herrmann [18]	2013	Journal	Approaches To Learning, Cooperative Learning, Engagement
Hone [19]	2016	Journal	Massive Open Online Courses, Distance Education

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Table 2.1 – continued from previous page

Reference	Year	Publishing Location	Topic Area
Jain and Kapoor [20]	2015	Journal	Peer Effects, Social Networks, Education
Johnson [21]	2006	Journal	Education, Survey, Virtual Study Group
Junco and Loken [22]	2011	Journal	Cooperative/Collaborative Learning, Learning Communities, Social Media
Kahu and Picton [23]	2017	Journal	Educational evaluation, Simulated Teaching Method, Student Activities
Kara [24]	2021	Journal	Online Content, Online Assignments, Online Assessment, Instructor Behaviors
Nam and Zellner [25]	2011	Journal	Cooperative/Collaborative Learning, Interactive Learning Environments
Péter et al. [31]	2016	Journal	Education, Offline Presentation, Online Presentation, Student Achievement
Punnoose [30]	2012	Journal	Behaviour, E-learning, Motivation
Rizvi [32]	2019	Journal	Distance Education, Lifelong Learning, Teaching/Learning Strategies

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Table 2.1 – continued from previous page

Reference	Year	Publishing Location	Topic Area
Romero [33]	2013	Journal	Distance Education, Tele-learning, Asynchronous Discussion Forums, Social Network Analysis
Rybczynski and Schussler [34]	2011	Journal	Study Groups, Group learning, Cooperative Learning
Sadykova [35]	2012	Journal	Online Learning, International Students, Peer-To-Peer Learning, Culture, Sociocultural Framework
Shi and Oliveira [37]	2019	Journal	E-Learning, Massive Open Online Courses, Learning Analytics
Smith and Johnson [39]	2005	Journal	Cooperative Learning, Problem-based Learning, Student Engagement
Sunar et al. [41]	2012	Journal	Social Network Analysis, MOOC, Peer Interactions
Tessier [42]	2007	Journal	Group Learning, Peer Teaching
Tulaboev and Oxley [43]	2012	Journal	Web 2.0, Social Networking, Higher Education
Vrioni [44]	2011	Journal	Education, Group Learning, Lecture, Students
Wentzel and Watkins [46]	2002	Journal	Collaborative Learning, Academic Enablers

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Table 2.1 – continued from previous page

Reference	Year	Publishing Location	Topic Area
Williams [47]	2011	Journal	Group Work, Cognitive Load, Friendship, Action Research
Wolff [48]	2013	Journal	Virtual Learning, Student Data, Distance Learning
Yang [49]	2012	Journal	Collaborative learning, Cooperative learning, CSCL, Historical review
Zhang and Sun [50]	2019	Journal	Student Engagement, Collaborative Learning, Social Influence

2.4 discussion

2.4.1 rq 1 does engaging in a study group foster a greater interest in a subject?

The question of whether engaging in study groups fosters a greater interest in a subject is a topic of significance in higher education. This literature review examines the implications of study group participation on students' interest in academic subjects, considering key factors such as self-confidence and active engagement.

Brindley and Walti [4] define engagement as student-faculty interaction, peer-to-peer collaboration and active learning".and they further state "it has been positively related to the quality of the learning experience. Social learning or learning as part of a group is an important way to help students gain experience in collaboration and develop important skills in critical thinking, self- reflection, and co-construction of knowledge".

As Arendale and Hane [2] observed, "This engagement was manifested through increased talking, the display of increased comfort while speaking, the asking of questions of the PAL (Peer Assisted Learning) facilitators and others in the group, and with the taking of initiative to answer questions rather than remaining silent and listening." The research of Arendale and Hane [2] underscores that as group study sessions progress, students exhibit a substantial increase in engagement and a growing familiarity with the group setting, indicating a correlation between this engagement and enhanced understanding of subject matter.

Moreover, the study by Johnson [21], which compared a discussion group utilising reciprocal peer questioning with a group using only mnemonic devices, revealed that "There were no differences between the two study conditions in terms of academic achievement. However, students in the reciprocal peer questioning condition made more postings and read more articles than students in the mnemonics group." While the academic outcomes remained unaffected, the heightened engagement led to students engaging in self-motivated learning, conducting additional research beyond the study group discussions.

In work completed by Alem and Kravis [1] exploration of online learning community, participants were categorised into two distinct groups: active contributors and 'Lurkers.' Active contributors engaged more actively in discussions, while 'Lurkers' primarily observed without participating actively in the conversations.

Alem and Kravis [1] noted that even those who primarily observed, "saw value in the discussion ", "and they were satisfied with the social interaction within the community." They found satisfaction in merely being part of the community and experiencing the social interaction it offered. This finding is particularly noteworthy, as it demonstrates that participation, even when minimal, holds a distinct role in enhancing students' interest in the subject. This highlights the value of participation extends to both active contributors and those who primarily observe. This study provides an intriguing perspective on the broader impact of online learning communities. It highlights the importance of creating inclusive environments where even passive engagement can foster interest and satisfaction among students, thus contributing to their overall learning experience.

In the context of Massive Open Online Courses (MOOCs), research by Sunar et al. [41] has highlighted the significance of social engagement in learners' academic success. Sunar et al. [41] findings reveal that when participants start following their peers the probability of their successfully completing the course substantially increases. However, the impact is more profound when these participants actively engage with their peers.

The act of "following" suggests an initial interest or admiration for the content or expertise of another participant, signifying the communal aspect of learning. This indicates the potential motivation that comes from connecting with peers, ultimately enhancing the likelihood of course completion. Furthermore, when participants not only "follow" their peers but also engage in substantive interactions. These interactions foster increased engagement, shared insights, and the nurturing of a supportive learning community within the MOOC.

Within a fully online course such as a MOOC Shi and Oliveira [37] establish the role an instructor must play to motivate engagement within online study groups. It is important for the course instructor to encourage learners to interact with peers, as this may further learning. We must take care to consider the facilitation of effective collaborative learning and embed effective social tasks that students can use to conduct collaborative learning such as discussion forms and online study groups. Chen and Chen [7] found that after implementing study groups into MOOC's "Affectively, the MOOC students generated more impetus for learning, and they disclosed apprehensions and worries that relieved inner pressure and dropout intentions. Participants became more active trying out new courses and learning strategies".

According to the work of Zhang and Sun [50], effective study group engagement can be broken down into three parts "relating, creating and donating". Relating refers to the group understanding of the problem at hand, creating relates to the group effort to find a solution to the problem and donating refers to the individual contribution to the groups success. Each piece is need to ensure students achieve a positive outcome of the collaborative work and remain focused on the goal of the group. Smith and Johnson [39] explore these three elements through the pedagogies of engagement particularly focusing on collaborative learning and problem solving. They are findings included "One way to get students more actively involved is to structure cooperative interaction into classes, getting them to teach course material to one another and to dig below superficial levels of understanding of the material being taught."

A study conducted by Williams [47] explored the affect of study groups as a tool for engaging students with class material. They identified that "By providing a co-operative learning context (an approach to group work, in which students work together towards a common goal) peer relationships can act as motivators for engagement in academic tasks". Their work involved constructing a number of group tasks for an introductory psychology course and surveying participants. They identified two major themes, firstly that friendship and the degree in which students knew their group provided stronger communication. "Communication was seen as a vital benefit of group work". Secondly self/external involvement, "The data indicates that in addition to students' valuing the role they played in their learning, they also valued input from external sources, i.e. the tutor, for support and guidance". They then asked participants to complete quizzes based on the task content and findings resulting from these quizzes would suggest that students learnt more during group tasks.

Wentzel and Watkins [46] documented the relationship between peers and collaborative learning as contexts for academic enablers. Their study found links between social interactions and facilitating collaborative learning. Within their study they examined motivation and interpersonal skills as cognitive enablers for academic success. They concluded that "Although motivation and interpersonal skills have been presented as somewhat independent from cognitive enablers, it is clear that these social and intellectual processes can work in integrated fashion to promote positive academic outcomes at school".

The work of Dolmans and Schmidt [15] reviewed the state of research completed on the cognitive and motivational effects of group learning and group study. They found "Studies focusing on the motivational effects indicate that discussion in the group stimulates students' intrinsic interest in the subject matter". Moreover they noted an increased focus of innovations in problem based learning. The results of these studies demonstrate that these innovations seem to have positive effects on the motivational effects of problem based learning.

Herrmann [18] approached cooperative learning to study how to increase engagement for students in higher education using active learning . Their study conducted on an undergraduate class to assess the impact on 140 student's engagement levels. Concluded, "When cooperative learning was introduced in tutorials, students increased their in-class participation". They highlighted that to capture students motivation, "They need to see how engaging in discussion with peers makes a difference to their own achievement." thus, cooperative learning opportunities such as study groups should be integrated with the curriculum of their given study.

Clarke and Potvin [9] introduced "Learning and engagement strategies, such as collaborative learning, gamification, problem-based learning and social interaction" to quantify the effect of these approaches on engagement. They questioned if a combination of these strategies would result in a positive impact on student engagement and learning. They concluded that after seeing a rise of students participation and exam scores that the strategy did in fact produce a positive effect.

Kahu and Picton [23] explored introducing collaborative activities in class such as open discussion and practical tasks. These were "seen by students as important for holding their interest. An engaging activity could, to some degree, help compensate for a students lack of personal interest in the topic". Capturing a students interest through cooperative learning helped keep students focused on aspects of learning that did not initially interest them.

An element of students willingness to engage in study groups stems from their previous experience within study groups and their social skills. Rybczynski and Schussler [34] believe that "students who see a benefit to studying socially start off more likely to utilize study groups than those students who prefer individual studying.". A attribute that sets study groups apart from other forms of collaborative learning is that there can be a incentive to continue work in a social setting outside of class time as a opposed to collaborative work such as pair work or open class discussion. Rybczynski and Schussler [34] found that their cohort of students had gained such social skills and that "most students in this study who participated in study groups had a positive attitude about the experience and believed study groups helped their grades".

Zhang and Sun [50] investigated the effect of social and academic pressure on students engagement within a study group. Their study involved tutors reviewing individual and group contributions to a given problem. They suggest "students are more likely to be influenced by other team members and instructor when each one's effort is visible". Their results show that mutual trust, social influence and reward valence have positive influence on students' teamwork engagement. Furthermore, teamwork engagement has a positive influence on personal success. The impact of supervision from a tutor could help decrease the number of "free riders" who accept benefits of the study group without providing meaningful contributions themselves. Jain and Kapoor [20] report that such "students free-ride extensively on group assignments when effort is costly and the rewards are shared by all the members of the group. As a result, active engagement within the study group members is low, and students do not learn from higher ability peers".

Research by Sadykova [35] into multicultural online learning environments emphasises that "Peers become invaluable mediators of knowledge for international students who seek peer assistance to compensate for the lack of culture-specific knowledge and skills and to satisfy their interest in the host culture. "Peer-to-peer support is instrumental in bridging cultural knowledge gaps and enhancing students' interest in the subject." The study unveiled that, in multicultural online learning environments, peers assume a vital role as mediators of knowledge. International students, in particular, often seek peer assistance as a means to bridge gaps in culture-specific knowledge and skills. This study significantly contributes to our understanding of how social dynamics within multicultural learning environments can enhance students' interest in the subject, making it a valuable addition to research on peer interactions in education.

2.4.2 RQ 2 DOES THE USE OF AN ONLINE STUDY GROUP HELP IMPROVE A STUDENTS GRADES IN A SUBJECT?

A student's academic performance can be influenced by numerous factors, and in this review, we aim to explore the potential impact of online study groups on a student's grades, as well as gather strategies utilised in offline study groups and examine how we can bring these approaches to an online format. This literature review will comprehensively examine a series of studies to shed light on the role of online collaboration in enhancing students' academic achievements.

Arendale and Hane [2] explore this topic through their study of a peer-assisted learning program. Their study offers insight into the potential of online study groups. It is important to note their research results were gathered from observations recorded by the program facilitators. "These facilitators noted how students were better able to understand and explain the reasoning behind concepts in comparison to earlier in the academic term." As they progressed through the academic year it became apparent that students displayed an amplified ability to grasp and articulate complex concepts.Arendale and Hane [2] observed growth occurred not only in academic skills. This study shows promising evidence that implementing study groups can be beneficial to students academic success.

Next, we looked at the feasibility of creating a platform that could facilitate online collaborative learning. Tulaboev and Oxley [43] found that "As a result of the discussions and group meetings with students, the study revealed that Web 2.0 tools have the ability to connect the learning community enabling it to share information and to facilitate collective learning." Tulaboev and Oxley [43] showcased it is feasible to build a platform that can provide functionality to curate a collaborative learning experience online.

The work of Alem and Kravis [1] highlights the need for moderation in an online collaborative learning space. In their case they found moderation was necessary to ensure the discussion remained accessible to all levels and "to stimulate discussion on all points being raised but not taken up, and to broaden discussions amongst subgroups." The usage of moderation to prompt further discussion in study groups could be used to emulate work similar to that of facilitators studied by Arendale and Hane [2]. In theory, it could also be used to measure academic progress.

The connection between online peer-to-peer engagement and academic progress is investigated in the case study by Desai, Ramasamy, and Kiper [13]. They found a positive correlation was seen between the number of posts made by a student and their academic performance. They also noted that the use of structured discussions can provide useful insights into a student's collaborative patterns that are also evident in their final grade. A link can be drawn between a student's ability to gain feedback on their subject knowledge and the academic progress of the student.

Kara [24] highlights the downfalls of having no access to peers in an online environment. "In regard to the barriers, lack of peer support was the first barrier to the effectiveness of online learning.". Kara [24] concluded that university students in their cohort taking online courses have little chance to get peer feedback. Some studies also emphasised that peer feedback supports improvement in critical thinking and self-confidence skills of students, especially in online processes of higher education. Hence, lack of peer support can decrease the effectiveness of online learning. It is important that we acknowledge how online study groups can counteract these barriers.

The study by Babić and Kolar [3], while not yielding a direct positive result, signals a potential area of growth in collaborative learning. The study alludes to the fact that teacher-guided, collaborative learning can have a positive impact on students' academic progress. This study thus highlights the latent potential of structured online study groups led by educators as a means to enhance academic performance. It underscores the importance of exploring different models within online study groups to identify how collaborative learning can be optimised to boost student grades.

An online platform is not limited to one media type and can be used for sharing lecture material, notes and collaborative tools. A study conducted by Péter et al. [31] explores one such use case, a cohort of students were divided in two with one group having access to online presentations and the other having offline presentations. Three measurements were taken throughout the academic year, describing the grades of each group. Their results showed that average performance increased more with the online group than with the control offline group. Not only did the online group perform better on average, the group working in an online environment achieved significantly better results in all three measurements.

The work of Clarke and Potvin [9] with regards to learning engagement strategies showed a benefit for students who took part in collaborative learning, Not only did students feel more engaged in the topic but they noted "a statistically significant improvement in student learning, as reflected in the exam scores." Many university's currently introduce group learning as an element of the curriculum,Vrioni [44] studied the effects of group learning on academic performance looked at a university class where part of the curriculum was taught with group learning methods and part was taught in a traditional lecture format. They found a notable increase in sections of assessment which covered topics taught under cooperative learning. Nam and Zellner [25] examined the relative effects of group learning on student achievement in an online cooperative learning setting. They found a 19% variation in student achievement which could be attributable to group learning.

Junco and Loken [22] explored a experimental methodology of cooperative online learning. They utilised Twitter the social media platform for peer to peer communication. Students were asked to tweet their opinions on class material and reply to other students within their groups with feedback on their work. They found that not only can Twitter be educationally relevant in increasing student engagement but can improve grades and can be used as an educational tool to help students reach desired college outcomes.

The work of Tessier [42] involved students working in small groups to complete class assignments by teaching set concepts to each other. On the exams, students answered more questions correctly on the topics covered in group learning than compared to the material presented in the traditional lecture. Furthermore Burrowes [6] found that students implementing collaborative learning strategies scored significantly higher than students taught in the traditional lecture format.

Contrarily Jain and Kapoor [20] studied the impact of study groups and found that informal settings without expectations of joint production may be conducive to academic exchange in peer groups. In contrast, situations where students are expected to work together may suffer from classic free-riding problems that inhibit learning. The research of Rybczynski and Schussler [34] related study group use to performance on content exams, They explored patterns of study group use, and qualitatively described student perceptions of study groups. Although they found no relationship between study group use and an increase in academic performance, they did note that "Students who participated in study groups did, however, believe they were beneficial". Some of the benefits of study groups noted by Chiong and Jovanovic [8] were peer help, and peer support; in addition, the participation of a substantial number of students was extrinsically motivated by the prospect of getting a higher final grade.

2.4.3 RQ 3 What effect does the demographic of user have on their experience with the platform. E.g gender, race, college course, leaving cert results, first generation college students?

Bruffee [5] stated "Collaborative learning is a teaching and learning approach that involves groups of learners working together to solve a particular problem, complete a task, or create a shared artefact". As Yang [49] defined collaboration as a setting "where individuals are responsible for their actions, including learning and respecting the abilities and contributions of their peers" . Each student possesses a unique demographic shaped by their personal experiences. In this context, we aim to explore the commonalities among these demographics and investigate how they influence the experience of using an online study platform.

To comprehensively address this research question, it is imperative to examine the shared traits among students who respond positively to collaborative learning. Consider a subject like a introductory Computer Science (CS1) module, where many students entering university encounter programming for the first time. This implies that each cohort generally starts on an even footing, and it falls upon the students to engage with the material to the best of their abilities as reported by Hegarty-Kelly and Mooney [17] and Harmon and Erskine [16]. It is worth noting that Computer Science has a well-documented high failure rate in the first year, particularly in programming modules. In Ireland, the non-progression rate for first-year CS students was recently reported at 27% Patterson and Prendeville [29], the highest among all disciplines in higher education. Moreover, CS1 typically enrols a large number of students, and programming, often an individual task, can be quite frustrating. Struggling students might feel isolated and be reluctant to ask questions. Our aim is to explore how online study groups can serve as a potential solution to the challenges outlined in this literature review, benefiting all students regardless of their backgrounds.

Punnoose [30] discovered that "Collaborative learning, as a strategy, empowers each unique student to share and acquire knowledge from their peers, effectively putting theoretical knowledge into practice. While every student is distinct, many who engage in e-learning tend to display similar characteristics." Notably, Punnoose [30] found that three personality variables positively influence students in the realm of e-learning: high levels of conscientiousness and extraversion, along with low levels of neuroticism.

The work of Rizvi [32] provides some of the most in-depth research into how learners demographics play a part in influencing the outcomes of online collaborative learning. Rizvi [32] noted that past research search such as Hone [19] "uncovered little to no effect of learner demographics on retention. Similarly no differences in completion were observed between the two main MOOC platforms which students chose for their learning". Rizvi [32] examined further and preformed research on UK students enrolled in the Open University. Which is one of the largest online university's. Their research found that Region and the deprivation index of the where the learners lived while taking the course can successfully be used to predict learning outcomes of assessments conducted at different points in time throughout the course. One potential reason why Region might have had such a strong impact is related to the socio-geographic division of regions in the UK, and its related educational systems. Their second finding from Rizvi [32] was that prior education level generally was a less prevailing feature, especially in comparison to Region and deprivation index. The third finding of Rizvi [32] was that they found a small significant effect of age on overall learning outcomes. It is noteworthy here that as the online course advanced, Age became a more influencing variable in the predictive model than prior education. In their forth finding Rizvi [32] also examined gender as a demographic and concluded there is no linkage between gender and successful online learning. Similarly Romero [33] and Wolff [48] did discover that demographics play a role in effective use of online learning and it is important to consider mature students and students with disabilities who may be more inclined to take part in distance/online learning.

2.5 conclusion

In response to the first research question on whether engaging in study groups fosters greater interest in a subject, the studies we have explored provide crucial insights and suggest promising avenues for future research.

- Firstly, the research offers a compelling foundation for further examination of the long-term effects of study groups on students' interest in academic subjects. Understanding how early engagement influences enduring interest and career choices is a vital direction for future exploration.
- Secondly, investigating the impact of study groups in diverse subject areas and across student demographics is crucial for tailoring effective collaborative learning strategies. Educators can benefit from research that pinpoints which models work best for students of different disciplines.
- Additionally, the influence of online and hybrid learning environments on students' subject interest presents a relevant frontier. Future research should delve into the effectiveness of virtual study groups on the student population.

In response to the second research question, which proposes the question, *"does the use of an online study group help improve a student's academic results?* Collectively, these studies provided seven valuable insights:

- Online study groups can enhance students' understanding of complex concepts and boost their confidence, laying a foundation for improved academic performance.
- Creating platforms for online collaborative learning, offers potential tools for academic enhancement.
- Moderation is important in online collaboration and can potentially measure academic progress in study groups.
- There is a positive correlation between online peer engagement and academic success, highlighting the potential of study groups to improve grades.
- A lack of peer support in online environments can hinder academic effectiveness, emphasising the role of online study groups in providing essential peer interaction.
- There is potential for growth in collaborative learning through structured online study groups led by educators, offering an avenue for academic improvement.
- The facilitation of online media can have a positive impact on student performance, underlining the potential of online study groups.

In response to the third question, ***"What effect does the demographic of user have on their experience with the platform?"*** this section of the literature review delves into the significant question of how the demographic characteristics of users affect their experiences with online study platforms. Collaborative learning, as a powerful educational tool, allows diverse groups of students to interact, share knowledge, and put theory into practice collectively.

The research question prompts an exploration of commonalities among students from various backgrounds and how these demographics influence their interaction with online study platforms. Personality traits, such as conscientiousness, extraversion, and low neuroticism, play a role in enhancing the e-learning experience.

Going forward, it is important to understand that to provide the best experience on an online platform such as the one proposed; there needs to be prompting for traits such as those mentioned above and support for students who may be struggling.

Part II

DEVELOPMENT

3

METHODOLOGY DEVELOPMENT

3.1 INTRODUCTION

This chapter provides an in-depth exploration of the pedagogical methodology adopted in our research, outlining the initial development and subsequent iterations made during the case studies. The aim is to offer a comprehensive understanding of the procedures, instructions, and adjustments made during the research process.

3.2 PEDAGOGICAL METHODOLOGY

The pedagogical strategy developed to accompany the software application is at the core of our research. This strategy was not static; rather, it evolved through continuous refinement across several case studies, a process that was instrumental in achieving our research objectives. Our literature review suggested that the implementation of collaborative learning strategies could be particularly effective when underpinned by a well-defined, structured methodology. A significant insight gleaned during the requirements gathering phase was that some students were attending laboratories without prior engagement in active learning sessions related to the topic at hand.

Key elements were identified in our literature review, seen in Chapter 2 to address this issue, ensuring that our pedagogical approach was responsive, adaptive, and effective. These elements will be discussed in detail in the following subsections.

Our pedagogical approach was designed to integrate smoothly into the pre-existing active learning activities like those within the CS161 and CS162 course at Maynooth University. Within these modules, the activities involved weekly programming laboratories. At the beginning of each week, students were provided with 4-5 Java programming questions, based on the lecture topic of the week. The questions were designed to cater to a range of difficulty levels, thereby ensuring an inclusive learning experience that would challenge and engage students at various stages of competency. During their laboratory sessions, students used the MULE IDE described in Section 1.6.1 to work on and ultimately complete these questions. Once the lab had begun they were allowed to view a "hidden question" which combined elements used in the earlier questions and carried double the Continuous Assessment (CA) weight, thus providing a comprehensive and insightful evaluation of students' understanding and application of the week's topic.

Our approach was to take this hidden question and introduce a collaborative learning session wherein students would work in groups of four to create an algorithm that could solve the question. The session took place as the laboratory began. Students, rather than immediately beginning to code, were asked to take some time to understand the question and to make notes on how they would approach it algorithmically. Students were then placed into groups of four and left to work collaboratively towards a final solution. Both the personal and group work was completed on paper. Once students were satisfied with their answer or the set time had elapsed they could return to the MULE IDE and implement their algorithm. The total length of the session was 30 minutes and afterwards students were surveyed to give feedback on both their personal and group work.

3.2.1 METHODOLOGY INSTRUCTIONS

The initial stage of the implementation process involved the development of clear and precise instructions for both the students and the demonstrators involved in the Collaborative Learning Session (CLS). These instructions underwent minor modifications based on the learnings gleaned from each case study. In this way, the instructions evolved and improved over time, further enhancing the effectiveness of the CLS. This can be seen in Figure 3.1

Demonstrator instruction set

For this week's labs, the students will participate in a collaborative learning session like paired programming for the first thirty minutes. It is important to note that this session will **NOT** affect their CA assessment.
This work aims to help prepare them for their end of semester examinations, improve essential soft skills that are used in industry, and help them better form their solution to the hidden question.

What can be expected:

- We will be asking them to take five minutes to independently think through the hidden question for this week on bubble sorting and begin to form an algorithm on paper.
- You can use this time to make sure everyone on your row understands the purpose of this session.
- The students will then move into groups of 3 or 4 depending on availability within their rows, and they will spend twenty minutes working together to produce a complete algorithm.
- During this section, you can walk between groups asking probing questions such as
    - Does everyone understand the current algorithm?
    - What variables do you expect to use in this question?
    - How did you implement this in your individual work?
- It is important to make sure every student gets a chance to speak. If you think one student is dominating the conversation, try to get everyone involved by asking other students how they would approach this question.
- In the last five minutes of the session, you can go through your row and check that each student has produced some individual work paper and group work.
    - Place one tick next to their name if they showed some individual work and two if they have produced something as a group.

Figure 3.1: Demonstrator instructions

Demonstrators were encouraged to promote independent learning by limiting their assistance, except for clarifying the exercise within the first five minutes. This was intended to incentivise students to utilise and revise their own notes or lecture slides, thereby fostering a sense of ownership and personal responsibility for their learning. Subsequently, students were divided into groups of four, except when confronted with a uneven number of students, in which case we supplemented with groups of three as needed. This allowed for a rich exchange of ideas based on their individual work. For the next twenty minutes, demonstrators were tasked with observing group discussions, encouraging deeper and more meaningful conversations where necessary. This proactive monitoring was particularly crucial during the initial weeks as students adjusted to the activity. In the final five minutes, demonstrators conversed with the groups to verify the correctness of their answers, ensuring that each group member comprehended the developed algorithm. This period was also used to confirm that each group member had contributed to the final answer.

Students received a similar instruction sheet as seen in Figure 3.2 to the demonstrators, albeit with a few key differences. The students' sheet divided the time into a 5-minute segment and 25-minute segment, providing a clear structure for the session. The sheet also offered several ice-breaking questions designed to facilitate effective communication within the groups and help them stay focused throughout the session. An example of a simple algorithm, such as 'how to cook an egg in seven steps', was also provided to help students grasp the concept of algorithmic thinking in a relatable, concrete manner.

Student's instruction set

This week, you'll be participating in a collaborative work session as part of your lab. You will complete this session in the first 30 minutes of your lab. It is important to note that this session will **NOT** affect your CA assessment.

A summarised guide is available below.

What can be expected:

- Mule will open the hidden question at the start of your lab as usual.
- This session will ask you to think through the hidden question on paper independently for 5 minutes.
- Thinking about the following may help you get started
    - What is the question asking you to do?
    - What variables will you need to complete the question?
    - Will you need conditionals or loops?
    - Can the question be broken in to smaller pieces?
- For approximately 25 minutes, you will then work collaboratively with a small group of classmates to produce an algorithm for the question.
- This algorithm will be shown to demonstrators in the last 5 minutes of the session.
- You must show your individual work and teamwork to a demonstrator at the end.
- There will also be two optional surveys for you to participate in, which will help one of your demonstrator's research project.

What is an algorithm?

An algorithm is a detailed sequence of steps required to solve a problem.

Example of algorithms:

<u>How to cook an egg</u>

1. Fetch a Saucepan
2. Half fill with water
3. Place saucepan on cooker
4. Apply heat to boil water
5. Place egg in boiling water
6. Keep boiling for 3 minutes
7. Remove egg

Figure 3.2: Student instructions

3.2.2 TIMING

The allocation of time was an essential attribute that required continuous adjustments throughout the initial stages of implementing the pedagogical methodology. The challenges associated with effectively managing time within the CLS became evident as groups progressed at different rates. The original time allocation was kept at 30 minutes per session, but other aspects of timing were refined based on feedback and observed student behaviours.

After careful review of session recordings and post-session discussions with students, it became clear that the initial allocation of 5 minutes for independent work was insufficient. Students reported feeling rushed and unable to thoroughly explore the problem within this time-frame. Therefore, we extended this independent work phase to 10 minutes, consequently reducing the group discussion time. This modification not only allowed students more time to formulate their own understanding of the problem, but also promoted a more active contribution during the subsequent group discussion.

An unforeseen issue emerged with groups of students who had a stronger grasp of the topic. These groups were finishing the exercises before the 30-minute session concluded, resulting in underutilised time. To address this, we introduced a second "hidden" question within the lab. This allowed groups that finished early to continue their productive engagement by working on an additional problem. This adjustment not only maximised the utilisation of the allocated time but also provided an additional layer of challenge for the more advanced groups.

Furthermore, we refined the instructions to emphasise the importance of shared understanding within each group. This was a response to observations that, in some groups, a few members were dominating the problem-solving process, thereby limiting the learning experience for others. By encouraging students to ensure that all members comprehended the final algorithm, we promoted a more equitable and enriching collaborative learning experience.

3.2.3 DETAIL OF ANSWERS

Our initial instructions did not adequately guide the students regarding the length or detail expected in their algorithmic answers. This lack of clarity could potentially lead to a wide range of responses, varying in terms of complexity and detail. It became evident that this could impact the effectiveness of the learning process and the comparability of results across different groups.

To rectify this, we provided an example question, paired with a model algorithmic answer that was relevant to the current topic. This served a dual purpose. First, it provided students with a clear expectation of the level of detail required in their responses. Second, it provided an additional learning resource, contextualising the abstract concept of algorithms within the framework of the topic being studied.

Presented in Figure 3.3 is a demonstration of the level of detail expected in an algorithmic answer. The question involves writing a Java program for a Binary search through a sorted array, a topic which aligns with the teaching content.

3.2.4 GROUP SIZES

Initially, the instructions recommended that students should form groups of three or four. However, after the first session, we observed that this range allowed for significant variability in group dynamics and the resultant learning experiences. A group size of four was found to encourage a broader range of perspectives and fostered a more comprehensive discussion, while a group size of three could limit these aspects.

As a result, we modified our methodology to adopt a more structured approach of maintaining groups of four students only. In instances where there were an uneven number of students, an exception was made to form as few groups of three as possible. This ensured a more consistent group interaction pattern across the study, enhancing the comparability of our observations and results.

```
Question
Write a Java program to complete a Binary search through a sorted Array.
You can assume the inputed array will be sorted.
You can assume the number to be searched for will be an integer.

Answer
Declare Ar as the sorted array, N as the size of the array, num1 as the
    value to be searched
Set the low equal to 1 and the high equal to N
while num1 is not found
    Set the middle equal to low + ( high - low ) / 2
        If Ar [ middle ] < num1
        Set low equal to middle + 1
        if Ar [ middle ] > num1
        Set high equal to middle + 1
        if Ar [ middle ] equals num1
        Exit "X is found at location middle"
    end while
end Method
```

Figure 3.3: Example Programming Question and Answer

In addition, maintaining a uniform group size allowed for a more structured comparison between different groups, and made it easier to control for group size as a variable in our research.

3.3 Surveys and Feedback

This section provides an in-depth analysis of the surveys implemented throughout the course of our studies, along with the methodologies devised to ensure that the feedback collected was relevant to answering our research questions.

3.3.1 microsoft forms

Microsoft Forms[2] was a primary tool used for collecting survey data. We chose this platform over alternatives like Survey Monkey[3] due to it being the survey platform recommended by Maynooth University for research purposes as well as its convenience integrating with Maynooth student accounts and the advanced functionality it offers. Not only did Microsoft Forms enable rapid survey creation, but it also provided tools to manage student data securely and anonymously.

Being a part of the Microsoft Office 365, it allowed seamless integration with our participants' email accounts enabling quicker and simpler gathering of data. We were also able to quickly download and view our data in Excel for further analysis.

Given that our target audience consisted of Maynooth University students, the platform offered an added layer of security by limiting survey participation to users with a Maynooth University address. Furthermore, it is pertinent to mention that we gained ethical approval for the gathering and storage of all data collected in this research.

3.3.2 the introductory survey

Our initial survey aimed to gather demographic information on our students. This information helped us create student profiles which were beneficial when grouping students and comparing data across various weeks.

The survey incorporated questions addressing the following aspects:

1. **Consent Confirmation:** Participants confirmed their consent to partake in the research study and acknowledged their understanding of their rights, the nature of the study, and data management practices.

2. **Age:** Participants provided their age.

2 `https://forms.office.com/`
3 `https://www.surveymonkey.com/`

3. **Previous Education:** Participants indicated whether they had previously completed a third-level course.

4. **Study Area of Previous Course:** Participants stated the area of their previous course(s).

5. **Current University Course:** Participants stated their current course of study.

6. **Gender:** Participants identified their gender.

7. **First Generation College Student Status:** Participants revealed whether they were the first in their family to attend third level education.

8. **Leaving Certificate:** Participants confirmed whether they had taken the leaving certificate.

9. **Leaving Certificate Points:** If they had completed it, participants shared their leaving certificate points or provided an estimate if they were unsure.

10. **Background:** Participants identified whether they come from a rural or urban background.

11. **Group Study Experience:** Participants indicated their prior experience with group study.

12. **Helpfulness of Group Study:** Participants rated the usefulness of previous group study experience on a scale of 1 to 5.

13. **Interest in CS Focused Group Study:** Participants expressed their interest in participating in a computer science-focused study group.

By focusing on these aspects, we were able to align our data collection with the proposed research questions, thereby ensuring that the feedback collected was not only informative but also relevant to our research objectives. The full survey as provided to students can be found in Appendix **??**

3.3.3 SESSION SURVEY

Unlike our introductory survey which was only given once at the first CLS, our session survey was provided to the students at the end of each weeks CLS. This survey focused on how students felt during the session and their confidence in the topic.

The following topics where covered in the survey:

1. Consent Confirmation: Participants confirmed their consent to partake in the research study and acknowledged their understanding of their rights, the nature of the study, and data management practices.

2. Session Type: Participants identified whether they had taken part in an online or offline session this week.

3. Session Rating: Participants were asked to rank on a scale from one to ten how helpful did they find the 30 minute session. With one being not helpful at all and ten being extremely helpful

4. Working preference: Participants indicated whether they preferred working on their own, with a group or had no preference either way.

5. Individual Work Rating: Participants were asked to rank on a scale of one to ten how helpful the individual work was.

6. Group Work Rating: Participants were asked to rank on a scale of one to ten how helpful the Group work was.

7. Feedback form: Participants could optionally fill in feedback about the session.

By including these topics in our weekly questionnaire we could map out how each session was progressing and identify quickly where there were issues if they arose. It also allowed us to map out each students confidence in their abilities and understanding of the given topic.

3.3.4 VERBAL FEEDBACK

Within our sessions we also collected verbal feedback. During and after our sessions our demonstrators would gather feedback from students on how the session went. Comments were recorded anonymously and provided greater insight into how the session had gone.

4 APPLICATION DEVELOPMENT

4.1 OBJECTIVE AND CHALLENGES

During development, we aimed to create a software tool aligning with our pedagogical approach. While our intentions were clear and driven, we inevitably faced challenges. Insights from our literature review and preliminary study illuminated these hurdles, especially the imperative for an intuitive tool that caters to varied learning speeds and bolsters effective group interactions. With this understanding, we laid out a distinct roadmap for our software's trajectory, ensuring that it not only met the needs of our methodology but also enriched the students' overall learning experience.

4.2 REQUIREMENTS GATHERING

The purpose of gathering requirements was to comprehend the needs and preferences of our target users - undergraduate students. Through interviews and surveys, we gathered feedback about students' experiences with existing collaborative and online learning tools. A sample of first-year undergraduate students trialling a similar methodology focused on offline collaborative learning provided further valuable insights.

Students' feedback was central to our design process. They conveyed a clear desire for a tool that offered more than just rudimentary features. Core functionalities like real-time chat, note-sharing, and progress tracking between multiple modules were paramount. Many students expressed the need for advanced features like voice and video chat. This feedback solidified our resolve to develop an application that was truly student-centric. Every feature and function we integrated was a direct reflection of this feedback, affirming our commitment to enhancing online collaborative learning.

4.2.1 EVALUATION OF REQUIREMENTS

Once the requirements were collated, a systematic evaluation was crucial to ensure relevance and feasibility. Drawing from the feedback and insights, we classified the requirements into "essential" and "desirable". Essential requirements were those critical to the core functionality of the application, directly supporting the collaborative learning framework. Desirable requirements, on the other hand, while not critical, would enhance user experience and engagement. An overview of the evaluation of the application requirements can be seen in Table 4.1

Table 4.1: Evaluation of Application Requirements

No.	Requirement	Classification
1	Real-time chat	Essential
2	Photo-sharing	Essential
3	Note-sharing	Essential
4	Progress tracking across modules and academic years	Essential
5	Video and voice chat	Desirable
6	Screen sharing and virtual white boards	Desirable
7	Real-time document collaboration	Desirable

4.2.2 DESIGN

In the design phase, we underscored the significance of maintaining industry benchmarks for both web and mobile platforms. The user stories derived from our requirements gathering phase acted as the foundation upon which the design process was built.

Transitioning from the ideation phase, our initial design sketches, manually illustrated, were translated into digital wire frames. Using tools such as Figma[4], these mock-ups underwent various iterations, evolving into a comprehensive design representation of both the web and mobile interfaces. Figures seen in Appendix A.1, Appendix A.3 and Appendix A.4 depict the design transformation from the initial to the final stages. Through continuous engagement and feedback loops with potential users, our design was constantly refined to ensure it resonated with our target audience and met the needs of our pedagogical approach.

4.3 AGILE METHODOLOGY

Agile is an adaptable methodology for project management particularly used in software development. It facilitates iterative development, allowing projects to be built incrementally, with a focus on continuous deployment, making sure there is always a product available to users. In the context of this study the users were our cohorts of students.

In this project, the Agile principles guided the development:

- **Iterative Development:** The application was developed in stages, each building and refining upon the previous.
- **Feedback Integration:** After each development phase, feedback was gathered and integrated to ensure the application met evolving user needs.
- **Adaptive Strategy:** While starting with an initial plan, the approach remained flexible, adapting based on emerging challenges and insights.
- **Stakeholder-Collaboration:** Maintaining open communication with the participants, module lecturers and regularly reviewing progress was crucial to ensure alignment with the project's objectives.

Using Agile, the application was iteratively refined, ensuring it remained effective for facilitating collaborative learning in an online/hybrid environment.

4 https://www.figma.com/

4.4 DEVELOPMENT CYCLE

The Agile development methodology was adopted for this project, facilitating a fast and iterative approach to the construction of the application. Despite having various interpretations, all Agile methodologies encompass the core stages of:

1. Requirements gathering
2. Product development
3. Software testing
4. Product delivery
5. Feedback assessment

This iterative approach enabled continuous improvement in the application as feedback from each release fuelled the requirements for the next cycle. After breaking down the necessary features and functionality into manageable segments, we applied this approach to each version of the project, taking it from requirements gathering to development, testing, and release as our study progressed. The management of this entire process was streamlined through Git. This cyclical development strategy allowed for consistent evaluation and improvement, ensuring that the application remained relevant and effective for the users.

4.5 WEB DEVELOPMENT

To facilitate our collaborative learning strategy in an online setting we first developed a web application to enable users take part in the methodology in a simulated remote environment.

This application was developed in two stages facilitating different levels of functionality as we progressed in our studies. The first version of the web application was utilised in our second study and included only the core features needed. The second version was built as the need arose when certain constraints limited some users from utilising the mobile application. Both versions of the web app were designed using the MERN (MongoDB, ExpressJS, ReactJS, NodeJS) tech stack and designed within industry standards for React development.

4.5.1 VERSION 1

The initial version of our app served as a foundational prototype of the online component from this research project. This version was pivotal in establishing the core features needed for an implementation of our methodology in an online environment. Through our requirements gathering, see Table 4.1, we had identified key features such as Messaging, Notes sharing, and photo sharing, which were essential for facilitating collaborative learning online. These features were carefully designed to align with our research objectives. An image of our first version of the web app can be found in Figure 4.1

In terms of development, our focus was on preparing these identified features for integration into the CS620C module, which constituted our second study. Due to impending deadlines, we prioritised creating a user-friendly interface that offered participants communication within their groups, while also streamlining the platform's administration and data collection processes. As part of our agile methodology implementing continuous deployment, we worked through our application requirements (see Section 4.1)from top to bottom beginning with implementing a real-time chat. As the beginning of the CS620C module course approached we acknowledged that our progressing tracking feature was not going to be completed in time and decided to postpone the feature to our second version.

Initial sketches transitioned into tangible designs, progressing from rudimentary paper wire-frames to refined digital mock-ups in Figma. With ReactJS from the MERN stack running the front-end, we hosted the application on Heroku (see Section 4.8.3). Comprehensive testing ensured functionality under potential real-world loads. However, challenges did arise. For instance, during large-scale user sign-ups, unexpected latency issues emerged. Despite prior stress-testing on Heroku, real-world implementation highlighted the need for bolstering our registration integration resources.

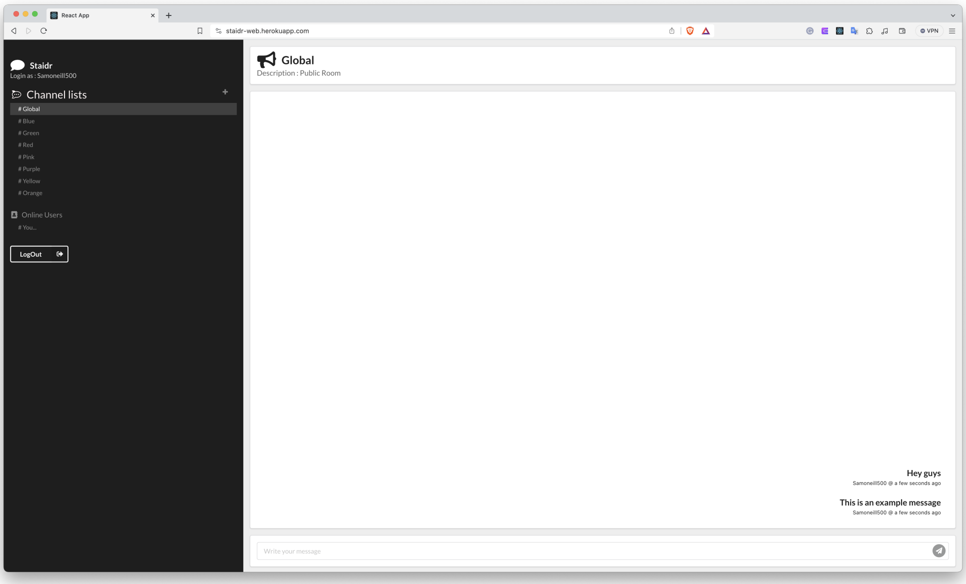

Figure 4.1: Web Application Version 1

4.5.2 VERSION 2

Our second version of the application was designed based on feedback from both participants and demonstrators during the second study. The most reoccurring pieces of feedback referenced to wanting more ways of accessing the application and to include more detailed note sharing system. These insights were invaluable in steering the evolution of the platform. Key feedback emphasised the need for expanded access options and a more comprehensive note-sharing system. We used this feedback and the backlog of features from our requirements gathering stage to structure our requirements for this next phase of development.

In the initial version, the application could be accessed through a web browser on participants' computers, but lacked a fully optimised user interface for mobile use. Our assessment also revealed the necessity for a more efficient group assignment system and improved activity monitoring. We began to standard-

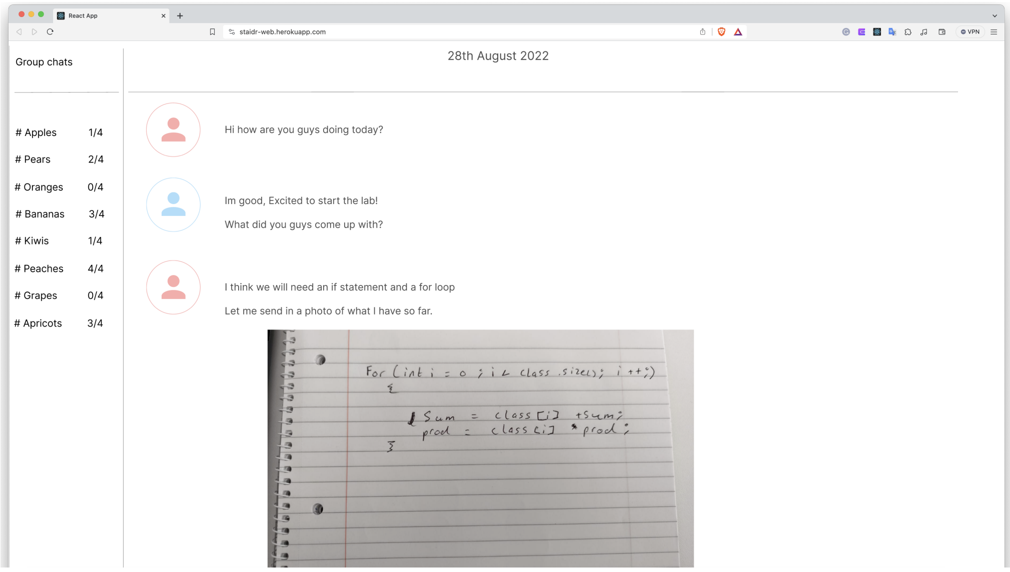

Figure 4.2: Web Application Version 2 Group Page

ise our user interface by planning what the final version of the mobile application would look like and replicating this in an web application format. Using this idea we created key UI components that could be implemented in both a desktop and mobile design. Introducing proper scaling when the user accessed the web page from a phone gave the impression of a mobile app in a web environment. It was missing some key advantages of mobile development that are discussed in the next section. An example of web app version 2 designs can be found in Figure 4.2 and further designs in can be found in Appendix A.2

We also overhauled our administration back-end for this version introducing an easier way to monitor large groups at once. We created functionality to assign students to groups quicker and to send out mass messages with prompts such as time keeping or encouraging messages to break the ice in our early session.

We laid the foundation for our last essential requirement to be able to track progress across multiple modules and academic years by introducing statistics and breakdowns of module content and participation on our homepage.

4.6 APP DEVELOPMENT

While our web application was a solid foundation for our facilitation of our collaborative learning strategy in an online setting, we wanted to go further and create a more enhanced user experience and provide offline and on the go access to the notes and content shared by our participants. Creating a mobile application does come with its downsides. Building a mobile app would mean starting again as React JS is not directly portable to React Native. There is also the issue of customising the code base for multiple OS's.

The version of the Mobile application needed to have the same level of functionality included in Version 2 of the Web application. This would allow students to have a fall back if there mobile device did not support the app or if they preferred to use the website.

4.6.1 MOBILE APP

Despite the change in platform, the Agile-inspired iterative development cycle remained our guiding principle. The mobile application mirrored the functionalities of the Version 2 web application, ensuring a consistent user experience across both platforms. Group assignments, refined messaging features, and the enhanced note-sharing system were pivotal elements integrated into the mobile ecosystem.

We utilised the same MERN tech stack by replacing ReactJS with React Native for mobile development which meant that we could keep our back-end and connecting services the same for each variation of the application. Transitioning to React Native from React JS posed a learning curve. Yet, by leveraging existing web app designs and functionality blueprints, we ensured coherence between the two versions. This dual-platform strategy enriched user choices, allowing them to engage with the collaborative learning environment via their preferred medium. A selection of screenshots of our mobile application are available in Figure 4.3 and further screenshots are available in Appendix A.5.

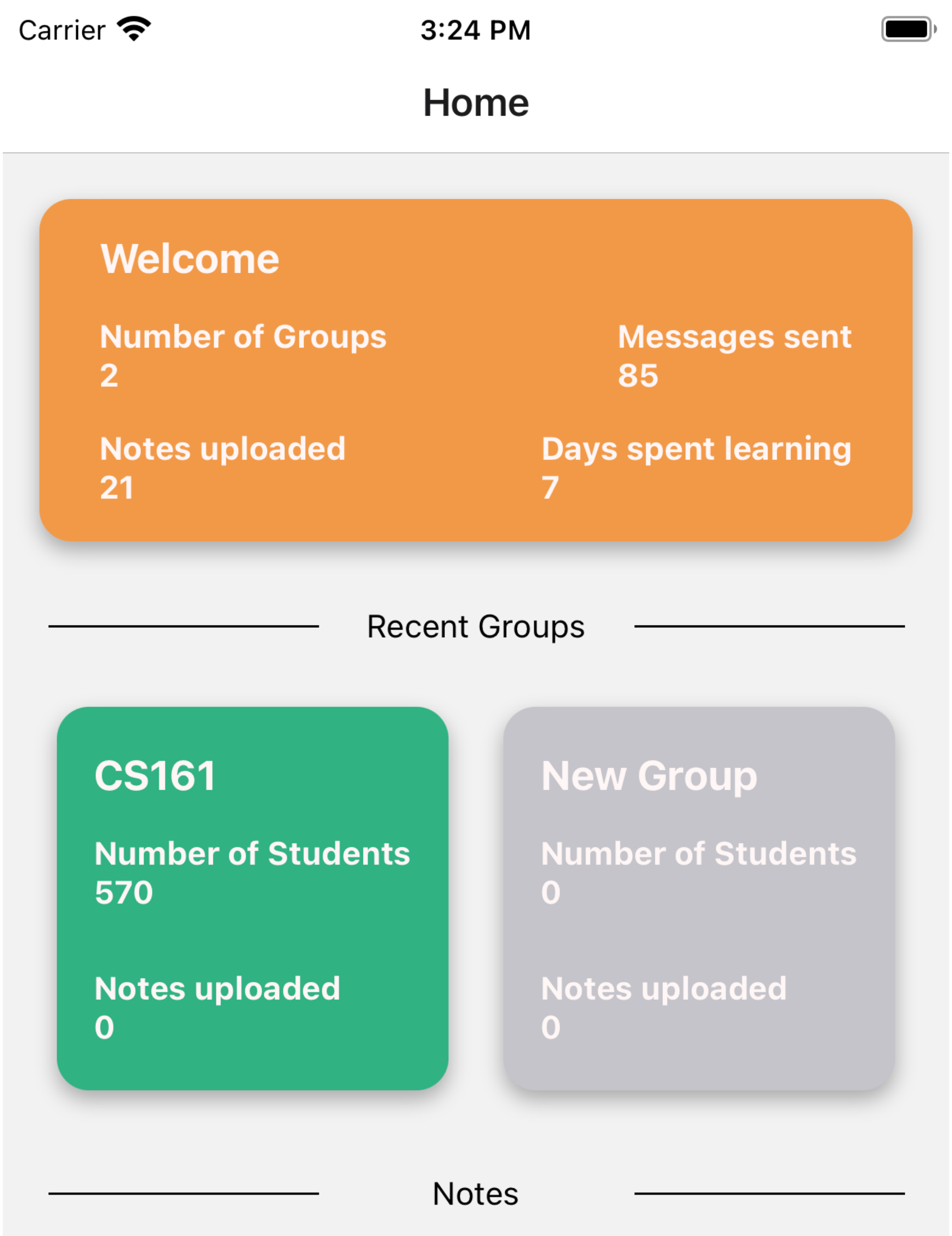

Figure 4.3: Mobile Application Home Page

4.6.2 UNDERGRADUATE STUDENT'S WORK

Regarding the note-sharing section, we identified a significant area for improvement. We recognised there was a demand for a wiki-like note space, enabling collaborative construction of a knowledge base. To address this, we collaborated with an undergraduate student as part of his final year project, providing him with a detailed design specification. Together, we held weekly meetings to co-develop this wiki-like feature for the application. Screenshots of this feature can be found in Appendices A.6 and A.7. This was a beneficial addition to our collaborative learning tool and gave students a space to collaborate outside of our sessions.

4.7 FRONT-END DEVELOPMENT

Front end development is where the core user experience comes to life. While back-end developers work behind the scenes to make a website or app function, it is the front-end that users see, touch, and interact with. For our project, our commitment to delivering a seamless and intuitive user interface was paramount.

4.7.1 REACT JS

React JS, developed and maintained by Facebook, has been our primary tool for building the web application. A JavaScript library, named React, allows developers to construct large web applications that can update and render efficiently without requiring the entire page to refresh.

What sets React JS apart from traditional JavaScript is its component-based architecture. Components are reusable pieces of code that serve as building blocks for an application. By segmenting our application into components, we could ensure consistency across different parts of the website while maintaining a modular approach to coding. This modularity made it easier to debug, improve, and expand the application over time.

Another advantage is the Virtual DOM (Document Object Model) that React employs. Instead of updating the entire page every time there is a change, React only updates the components that need it. This results in faster performance and a more efficient application, ensuring a smoother user experience. Which was key for a project with a chat component as its main user interaction.

4.7.2 REACT NATIVE

Transitioning to a mobile environment, we utilised React Native for the development of our mobile application. Much like React JS, React Native is also a product of Facebook, but it is tailored for mobile app development.

The beauty of React Native lies in its ability to allow developers to write the majority of their application's code in JavaScript and render it using native components. This means, rather than writing separate code for iOS and Android, developers can share a significant portion of the codebase between platforms. This cross-platform capability significantly reduces development time and ensures consistency in user experience across different devices.

However, React Native is not a mere replica of React JS. One key distinction lies in their handling of components. In React JS, developers deal with web components, while in React Native, they work with native components. This subtle shift requires an understanding of mobile-specific behaviours and standards.

Classes vs Functional

In the world of React, both Classes and Functional components play critical roles. Initially, React was primarily class-based, but with the introduction of Hooks in React 16.8, functional components became more powerful and versatile.

Class components come with lifecycle methods, allowing developers to run specific pieces of code at particular times in a component's lifecycle. They were the go-to choice for stateful components before the introduction of Hooks.

Functional components, on the other hand, are stateless and tend to be more concise. With the advent of Hooks, however, functional components can now manage state, handle side effects, and tap into lifecycle behaviours. This evolution has led many developers, including us, to favor functional components for their simplicity and efficiency.

For our project, we took advantage of both paradigms. We used class components where lifecycle methods were crucial, and functional components, augmented with Hooks, in areas where state management and re-usability were paramount.

4.8 BACK-END DEVELOPMENT

Back end development in the context of application development focuses on how data is processed and stored. This processing is completed on a server, as we utilised the MERN tech stack our server was built on ExpressJS and we used MongoDB to host our data. Other key aspect's for our project were scalability and security we deployed our server on Heroku and combined with Socket.IO we were able to provide scalable and secure functionality for our application.

4.8.1 MONGODB

MongoDB is a leading NoSQL database that became our chosen database solution for the project. Its document-oriented structure allows for flexibility in storing structured and unstructured data. This characteristic made it particularly suitable for our needs, as the collaborative learning environment demands diverse data types, from user profiles and group messages to shared notes and multimedia content.

Another key strength of MongoDB is its scalability. As our user base grew, MongoDB's horizontal scaling capability ensured that our application's performance remained consistent. Its built-in sharding feature distributes data across multiple servers, thereby balancing the load and ensuring uninterrupted service.

Furthermore, the MongoDB Atlas cloud service offered us benefits like automated backups, monitoring, and the ability to scale on-demand.

When developing our database structure we created schema to properly organise our data and allow our back-end to specify if we were querying: user information, message information or group information. An example of such a schema can be seen in Figure 4.4. Further examples can be seen in Appendix B.1 and Appendix B.2. We have also included a screenshot of how this looks on MongoDB when it receives a message in Appendix B.3. In this example Room_name refers to the identifier of that study group.

```
let messageSchema = new Schema(
  {
      Room_name: {
          type: String,
      },
    Edited_flag: {
      type: Boolean,
    },
      Is_image:{
        type: Boolean,
      },
    Group_id: {
        type: mongoose.Schema.Types.ObjectId,
    },
    Current_message: {
      type: String,
    },
    Original_message: {
        type: String,
    },
    User: {
        Email: {
            type: String,
        },
        User_id: {
            type: mongoose.Schema.Types.ObjectId,
        },
        Avatar: {
            type: String,
        },
    },
  },
  {timestamps: true},
);
module.exports = mongoose.model( name: 'messages', messageSchema);
```

Figure 4.4: MongoDB Message Schema Example

We then used express to build API endpoints for our server to connect to Mongodb and created CRUD (Create, Read, Update and Delete) functionality for our system. An example of how we added new messages to our database can be seen in Figure 4.5.

```
router.post( path: '/add', handlers: async (req : ... , res : Response<ResBody, LocalsObj> ) => {
  const Edited_flag = req.body.Edited_flag;
  const Is_image= req.body.Is_image;
  const Group_id= mongoose.Types.ObjectId(req.body.Group_id);
  const Current_message = req.body.Current_message;
  const Original_message = req.body.Current_message;
  const Room_name = req.body.Room_name;
  const User = req.body.User;
  const Avatar = req.body.avatar;
  const newMessage = new Message({
    Room_name,
    Edited_flag,
    Is_image,
    Group_id,
    Current_message,
    Original_message,
    User,
    Avatar,
  });

  if(req.body.Room_name != null) {
    console.log(req.body.Room_name);
    try {
      await newMessage.save();
      res.send(newMessage);
    } catch (err) {
      res.status( code: 500).send(err);
    }
  }
});
```

Figure 4.5: Express post request example

4.8.2 OAUTH

Security was a non-negotiable criterion for our application, especially when dealing with user logins and personal information. OAuth emerged as an ideal choice, allowing us to authenticate users without directly handling their passwords.

Our integration of OAuth focused on using "mumail" logins. By doing so, users can leverage their existing credentials, ensuring a smooth on-boarding experience. The advantage of this approach is twofold: It reduces the risk of exposing sensitive data as we do not store passwords, and it provides users with a familiar and trusted authentication method.

Moreover, OAuth's token-based system offers added layers of security. Once users authenticate, they receive a token rather than a constant open connection, minimising potential vulnerabilities. An example of this from our React Native code base can be seen in Figure 4.6. As our user opens the app their info is requested by supplying Autho with their access token. If no access token is available for example on first launch of the application we requested one as the user registers.

```
const getUserData = async access_token => {
  const accessToken = access_token
    ? access_token
    : await SInfo.getItem( key: 'accessToken',  options: {});

  const data = await auth0.auth.userInfo( parameters: {token: accessToken});
  return data;
};
```

Figure 4.6: Autho Token request

Importantly, our OAuth integration was designed to securely save user information directly to our MongoDB database. This automation not only expedited the user registration process but also ensured that user data remained protected, leveraging MongoDB's robust security measures.

4.8.3 HEROKU

Heroku[5]is a cloud platform that offers scalable and managed hosting solutions for web applications. For our project, it provided an environment where our back-end code could be effortlessly deployed, monitored, and scaled.

5 https://www.heroku.com/

Beyond its ease of setup, Heroku stands out for its seamless scaling capabilities. As our user traffic fluctuates, Heroku's dynos (containers) can be easily adjusted to meet the demand, ensuring that the application remains responsive even during high traffic periods.

Additionally, Heroku's integration's with popular databases and its extensive add-on marketplace ensured that our back end had all the necessary tools at its disposal.

As depicted in Appendix B.4, Integrating Heroku with Git we were able to deploy changes to our server as we committed to our code base and Heroku would automatically rebuild our dyno's to reflect these changes.

4.8.4 SOCKETS

The choice to utilise websockets emerged from our in-depth investigation into various methods for establishing real-time one-to-many and many-to-many communication systems.

Alternatives that we considered but ultimately dismissed included Server Sent Events (SSE) and Extensible Messaging and Presence Protocol (XMPP). SSEs, which are supported by numerous database platforms like MongoDB or Google Firestore[6], appeared less appropriate for our purposes. Although they are well-suited for transmitting single events such as push notifications, SSEs do not offer the same level of support for real-time messaging that we sought to implement.

XMPP, on the other hand, excels in providing a secure interface and is favoured by encrypted messaging platforms like WhatsApp. While this level of security was tempting, XMPP tends to require more computational resources and comes with an inherent complexity that made it less appealing for our project's scope.

After careful consideration, we determined the websocket based library Socket.IO to be the most suitable option. This decision was influenced by Socket.IO's

6 Firestore is a scalable NoSQL database offered by Google. `https://firebase.google.com/docs/firestore`

design as an event-driven library tailored specifically for real-time web applications. Additionally, Socket.IO provided an integrated infrastructure that accommodated both Node.js-based servers and a front-end development suite for web and mobile applications. This compatibility across different platforms made it a highly attractive solution, ensuring smooth and seamless data communication across various devices, essential for a collaborative learning tool.

Moreover, its low latency communication and capacity to handle asynchronous data transmission enhanced its appeal further. Socket.IO also allowed us to leverage namespaces and rooms, which offered the flexibility to create isolated communication channels, a crucial feature in a multi-user chat application.

In our code base our socket.IO functions were kept as concise as possible. When our server received a message it came with a destination (The study group) and a sender, we would then take this message as seen in Figure 4.7 and emit it to the destination chat before sending to the MongoDB database. This was due to the nature of websockets and the time taken to send a message between sockets is much smaller compared to the time taken to insert into the database.

```
socket.on( events.MESSAGE_SEND, ({ channel, msg }) => {
    let message = methods.createMessage( msg, socket.user.nickname )
    io.emit( events.MESSAGE_SEND, ({ channel, message }))
    let DBmessage = methods.sendToDb(message, channel);
    methods.pushToDB(DBmessage);
})
```

Figure 4.7: Socket Message Example

4.9 TESTING AND CHALLENGES

4.9.1 TESTING AND ITERATIONS

Rigorous testing phases, both in-house and with select user groups, underlined our development process. Feedback loops were integral, helping identify any pain points or areas of improvement. This iterative process, guided by Agile methodologies, ensured that subsequent versions of the app were refined and better aligned with user expectations.

4.9.2 feature parity

To maintain consistency, it was paramount that our mobile app mirrored the web version's functionalities. This encompassed group assignments, refined messaging, and the augmented note-sharing mechanism. However, mobile platforms also provided an opportunity to introduce unique features. Message notifications were implemented, ensuring immediate updates for users, fostering real-time collaboration. Offline access was another addition, allowing students to engage with content even without an active internet connection and sync data when online.

4.9.3 challenges

Transitioning from web to mobile was not without its hurdles. Managing device fragmentation, ensuring compatibility across various operating systems, and addressing different screen resolutions required meticulous planning. Additionally, as we were catering to a potentially large user base, scalability was a focal point. Cloud solutions and back-end optimisations were employed to ensure smooth performance even during peak usage times.

In conclusion, the mobile application's development journey was challenging and enlightening experience, reinforcing our commitment to delivering an inclusive and comprehensive online collaborative learning environment.

Part III

EVALUATING THE METHODOLOGY AND RESULTS

5

PILOT STUDY

5.1 INTRODUCTION

The following chapter describes the pilot study of our project taking place within the CS162 (see Section 1.6.2) module weekly laboratories. This study was conducted fully in person and acted as a test bed for our methodology allowing us to experiment with some of our variables and criteria before future studies trialled it in an online environment. We will discuss our approach to the study and present our analysis of the results with a particular focus on investigating the impact a students demographic can have on collaborative learning.

5.2 PILOT GROUP

5.2.1 TIMELINE

Our pilot study took place during the second semester of the academic year 2021-2022, spanning six weeks. Within this time-frame, we managed to conduct four collaborative learning sessions engaging our pilot cohort.

Before the Easter break, we launched our initial two sessions, which focused on the intricate topics of "Strings" and "Sorting Algorithms". Upon conclusion of the midterm break, we reconvened for the subsequent sessions, delving into more advanced themes: "Classes and Objects", followed by "Inheritance/Abstraction". This is detailed further in Table 5.1 which presents a timeline pinpointing the topic of each week and the number of participants who provided survey feedback.

Table 5.1: Timeline - Topic covered each week

Week	Date	Topic	Participants
1	March 31st	Strings	160
2	April 7th	Sorting Algorithms	113
3	April 28th	Classes and Objects	60
4	May 5th	Inheritance and Abstraction	36

An evident downtrend in attendance and participation emerged as the weeks progressed. In the first week, we explored the topic of "Strings", engaging 160 survey participants. The following session revolved around "Sorting Algorithms", with 113 students participating. After the Easter break, the third session covered "Classes and Objects", 60 students took part in the survey a noticeable drop off. Lastly, our final session centred around "Inheritance and Abstraction", attracting 36 participants completing the survey.

There exist multiple conceivable factors influencing the decline in survey participation, including fluctuating class attendance, the rising complexity of the posed questions, and potential overlapping commitments of the students.

5.2.2 PARTICIPANTS

The chosen cohort for our study consisted of pupils from the CS162 "Introduction to Computer Science II" module, as seen in Section 1.6.2. We partnered with Maynooth University's computer science faculty, as the labs provided a well structured environment in which we could facilitate collaborative problem solving.

Having previously completed the CS161 "Introduction to Computer Science I" module (detailed in 1.6.2), all participants brought to the table a foundational familiarity with programming. Over our six week experimental period students covered the topics as seen in Table 5.1. These labs were designed to introduce more complex programming concepts such as sorting algorithms and object oriented topics such as classes and objects.

In our first session we surveyed the cohort with our introductory survey. This survey focused on collating demographic and background data on the participants as discussed in Section 3.3.2. There was a noticeable difference in participants completing the introductory survey (n=202) and participants completing the first session survey (n=160). This could be due to students not understanding there was two surveys to be completed on the first day or an issue with motivation regarding completing the survey at the end of each session. We did take this on board to introduce better communication around the surveys for further studies.

While engagement metrics fluctuated across weeks, our initial introductory survey garnered feedback from 202 participants. We had a diverse cohort of students in terms of age, gender, educational and environmental background. This data is broken down in our Introductory session results, see Section 5.3.1.

5.3 RESULTS

5.3.1 INTRODUCTION SURVEY

As discussed above in Section 5.2.2 we utilised an introductory survey to build a demographic profile of our participants. We introduced this survey before beginning the first CLS. This survey had the most amount of respondent's of this study. The data gathered covered three main areas; Individual background, Educational background, Past collaborative working history. We chose these areas as they provided the greatest context for our research purpose.

Our questionnaire was structured as follows:

- **Individual Background**
  - Q1: What is your age?
  - Q2: What is your gender?
  - Q3: Are you from a rural or urban area?

- **Educational Background**
  - Q4: What is your current college course?
  - Q5: Are you a first generation college student?
  - Q6: Did you sit the leaving cert?
  - Q6b: What points did you receive in the leaving cert?
- **Collaborative Working History**
  - Q7: Have you previously taken part in collaborative learning?
  - Q8: How helpful did you find it in increasing your understanding of a topic?
  - Q9: Would you be interested in participating in a computer science-focused study group?

Q1-Q3: These questions are designed to capture the participant's demographic background, providing insights into their age, gender, and upbringing. This data can offer potential correlations with their learning experiences and educational preferences.

Q4-Q6: These questions focus on the educational background of the participants, aiming to identify their current academic focus and previous academic achievements. Specifically, the query about being a first-generation college student could shed light on the potential educational influences they might have experienced.

Q7-Q9: The final section refers to the participant's experience with collaborative learning environments. These questions can help identify the perceived effectiveness of such settings and the participant's willingness to participate in a similar setting in the future, particularly within the context of computer science.

Using the responses from our students we were able to group our students into clusters and analyse how their experience was affected within the CLS's

The introductory survey as provided to students can be seen in Appendix **??**.

5.3.2 INDIVIDUAL BACKGROUND

In the realm of education, individual characteristics can often influence learning experiences and academic choices. In this section, we will examine the personal attributes of our study participants. We aim to understand how such factors, including gender and environmental upbringing, can provide context for their academic journeys.

The data collected in this subsection provides insights into the demographic distribution of our participants. This information is essential for ensuring that our study represents a diverse range of backgrounds and experiences.

Age

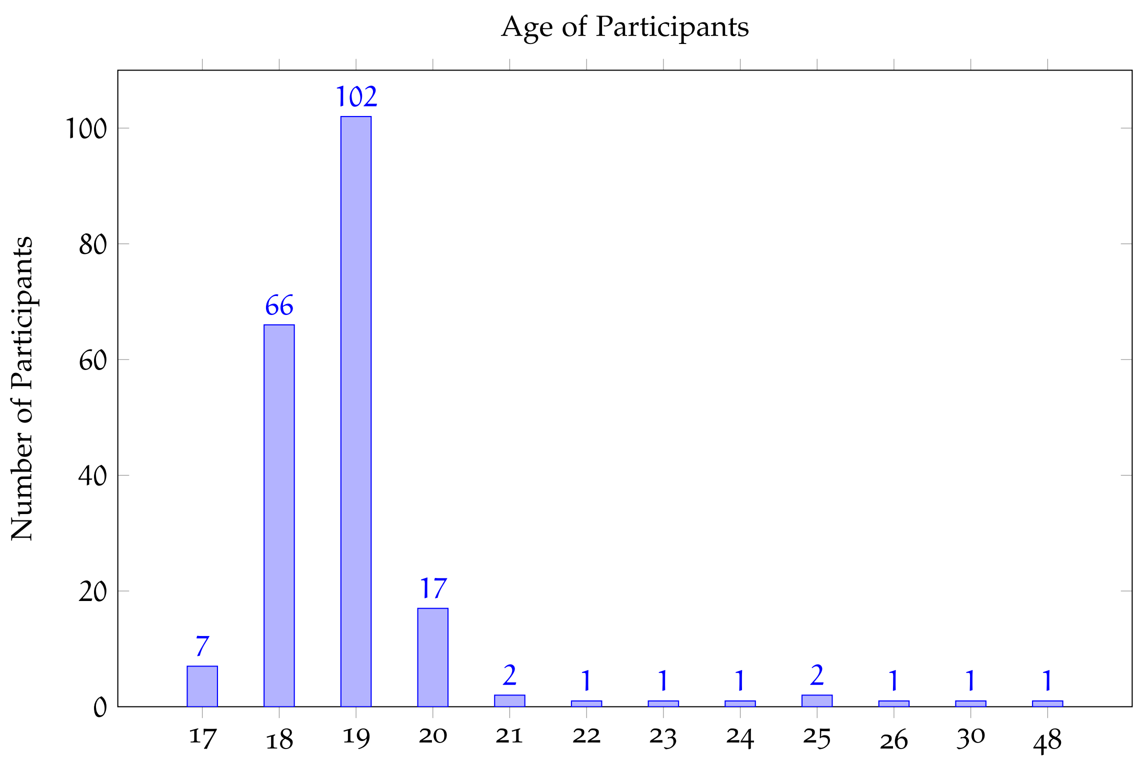

Figure 5.1: Age distribution of participants.

As showcased in Figure 5.1, we observed the ages of our participants ranged from 17 to 48 years. This wide range brings a variety of experiences and perspectives to our study. The predominant age bracket, however, was between

17 and 20 years, with 97.5% of participants falling within this range. This is understandable as the participants surveyed are in their early university years. The outliers, those above 20, add depth to our study, as their experiences and feedback can offer a diverse perspective, possibly rooted in different life and educational experiences.

Gender

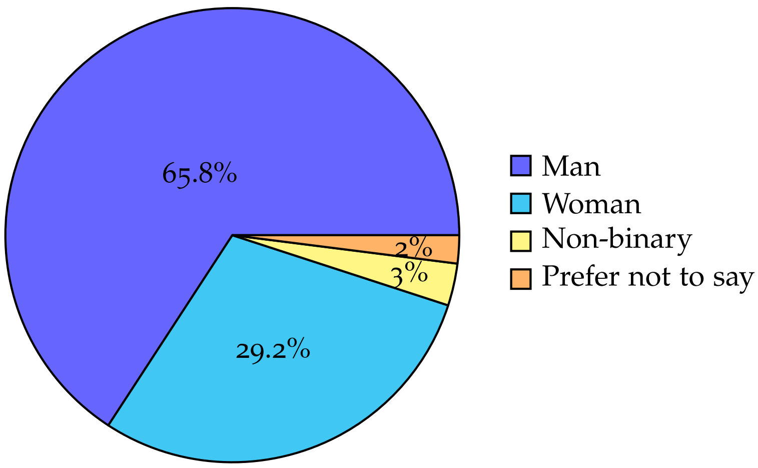

Figure 5.2: Gender distribution of participants.

The gender distribution, as illustrated in Figure 5.2, indicates a majority of our participants, 65.8% (133) to be precise, identified as Male. Following that, 29.2% (59) participants identified as Female. A smaller percentage, consisting of 3% (6) participants, identified as "Non-binary", while 2% 4 participants preferred not to disclose their gender, choosing "Prefer not to say". This distribution paints a clear picture of the gender diversity within our study. While there is a higher representation of males, it is crucial to recognize and value the contributions of each gender category. The diverse gender spectrum enriches our study by bringing varied experiences and perspectives. The higher representation of one gender over another may suggest potential biases in either the field of study or the participants' willingness to partake in the survey.

Environmental Background

The participants' backgrounds regarding their upbringing were distinctly divided into two categories: rural and urban shown in Figure 5.3. Out of the surveyed students, 69 participants, representing approximately 34%, identified as coming from a rural background. Conversely, the larger portion of the cohort, comprising 133 students or about 66%, indicated an urban upbringing.

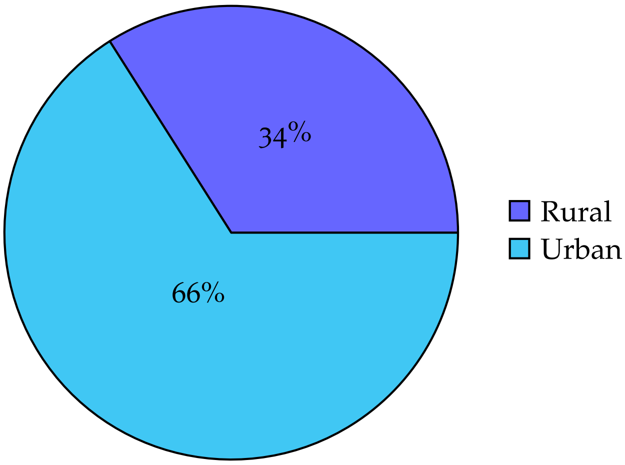

Figure 5.3: Environmental upbringing distribution of participants.

This distribution provides valuable insights into the diversity of the participants in terms of their environmental backgrounds. Understanding whether a participant comes from a rural or urban environment can provide insights into their previous exposure to collaborative or group-based learning. Students from urban areas might have had more opportunities for group projects and collaborative initiatives due to the density and diversity of educational institutions in their surroundings. Conversely, those from rural areas might have had different, more individualistic learning experiences due to the nature of schools in less populated areas. By analysing this distribution, we could better understand any potential advantages or challenges faced by students in CLS's based on their environmental upbringing.

5.3.3 EDUCATIONAL BACKGROUND

Educational backgrounds play a pivotal role in shaping students' academic choices, performance, and aspirations. In this section, we delve into the academic disciplines our participants are enrolled in, understand their parents' education level, and examine their previous academic achievements. Such data will offer insights into their current academic focus and how past educational experiences may influence their collaborative learning preferences.

This section's data helps us understand the academic landscape of our participants and potentially identify patterns or trends within certain educational backgrounds.

College Course

Maynooth University, through its diverse offerings, attracts students from a vast array of academic disciplines. The module CS161 allows students from different faculty's to take part and approximately 24 different courses are offered the module.

As illustrated in Figure 5.4, the dominant degree pathways among our participants are BSc Computer Science & Software Engineering, Bachelor of Science, and Bachelor of Arts.

These courses, by nature, encompass a broad spectrum of subjects, which is reflected in their larger enrollment numbers. In contrast, specialised courses like the BA in finance attract a niche audience, resulting in smaller class sizes. A noteworthy point is the mandatory inclusion of the CS161 module in certain courses such as Data Science, Computer Science, Quantitative Finance, Multimedia, Mobile and Web Development, Physics with Astrophysics, and Robotics and Intelligent Devices. This compulsory aspect could potentially influence the inherent motivation levels of students from these courses towards collaborative learning sessions.

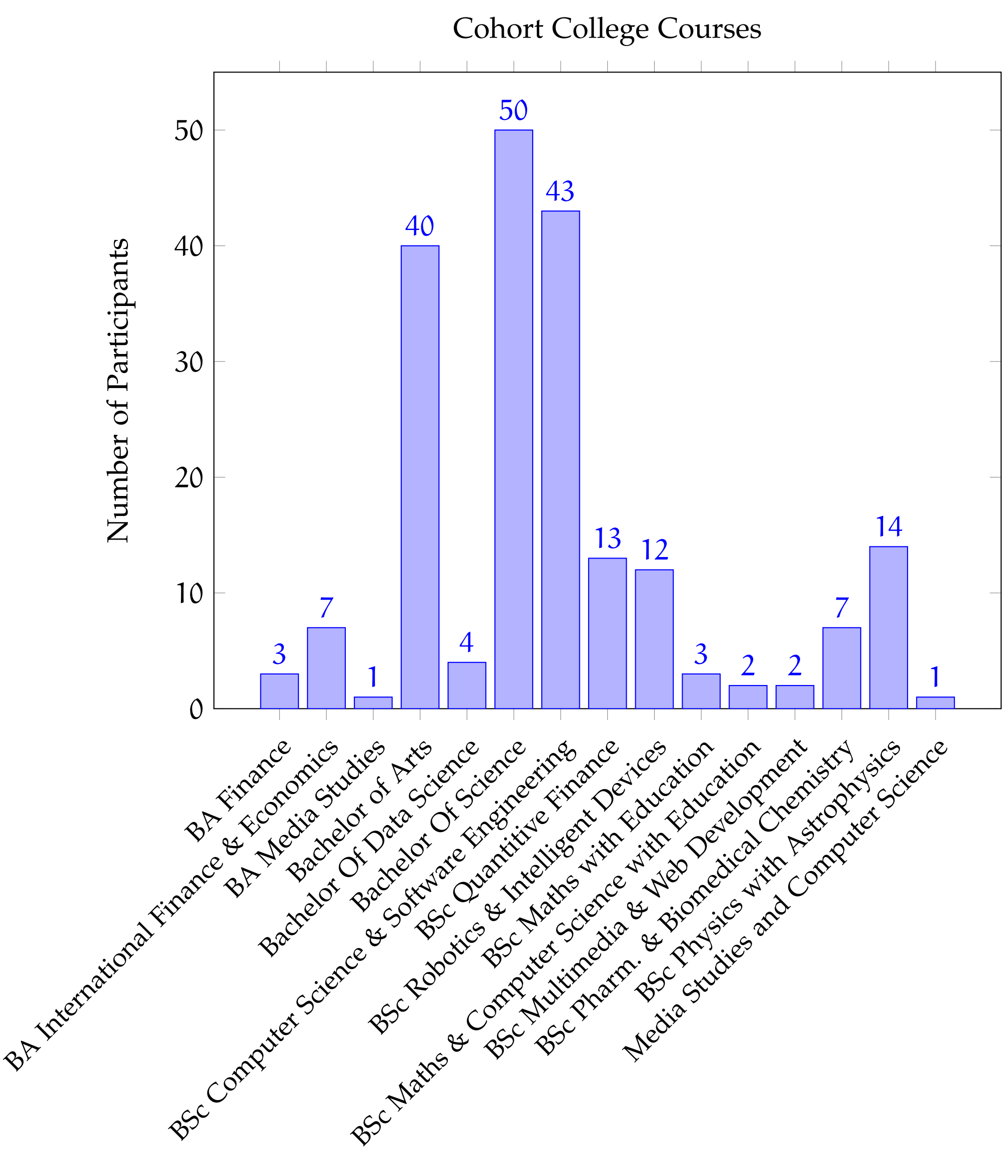

Figure 5.4: Cohort College Courses

Parental Education

Understanding whether participants are first-generation college students can provide insight into their family's educational background and potentially, their academic support structures. Being a first-generation college student might mean the individual does not have the direct family experience or guidance of navigating the academic rigors and environment of tertiary education.

From our participant data, it is noteworthy that a significant proportion, 93 participants or approximately 46%, identified as first-generation college students. This means they are the first in their family to attend college. On the other hand, 109 participants or roughly 54% mentioned that they are not the first in their family to pursue higher education, as illustrated in Figure 5.5.

This mix of backgrounds could influence collaborative learning in several nuanced ways. First-generation college students might approach collaborative learning with a unique perspective, potentially driven by their independent journey through academia. They might either be more inclined to seek peer support, given the absence of direct familial guidance, or conversely, be more self-reliant, given their likely experiences of navigating challenges independently. On the other hand, non-first-generation students might enter collaborative learning sessions with some preconceived notions or strategies passed down from family members, which could shape group dynamics and contributions.

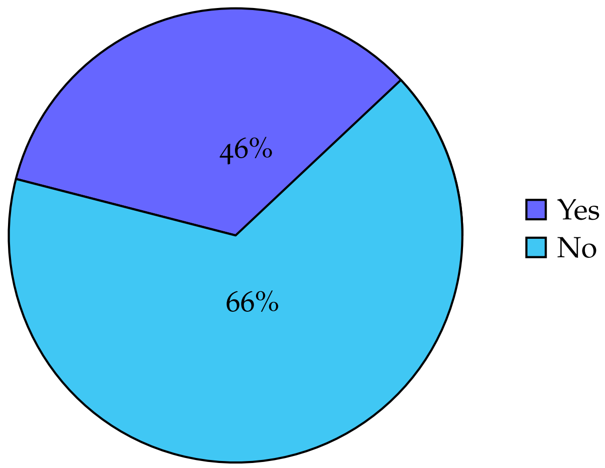

Figure 5.5: Are you a first generation college student?

Previous Academic Background

Although the leaving cert examination is typically thought of as self assessed tests. There can be element's of collaborative learning implemented in the continuous assessment section of subjects. Conversely, the students who did not undertake the leaving cert might bring alternative, valuable learning experiences and methodologies to the group, diversifying the group's collective approach to studying and problem-solving.

From our population a substantial 185 (91.5%) students have completed the Leaving Certificate, while 17 (8.5%) students did not, as illustrated in Figure 5.6. The spread of points achieved, shown in Figure 5.7, suggest a variety of approaches students may bring to collaborative study sessions. Those who have taken the leaving cert might bring structured learning methodologies to collaborative sessions, given the rigorous nature of the examination

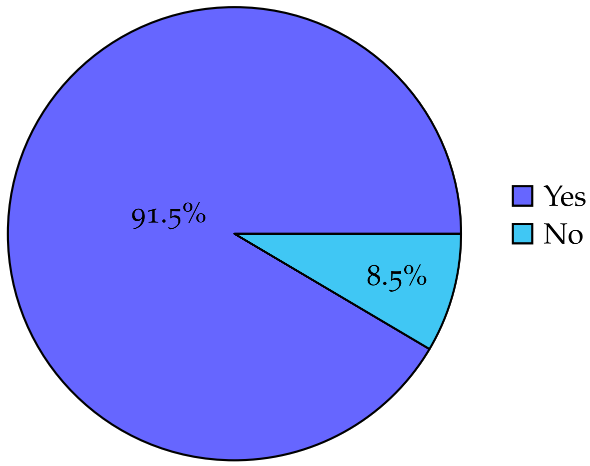

Figure 5.6: Did you sit the leaving cert?

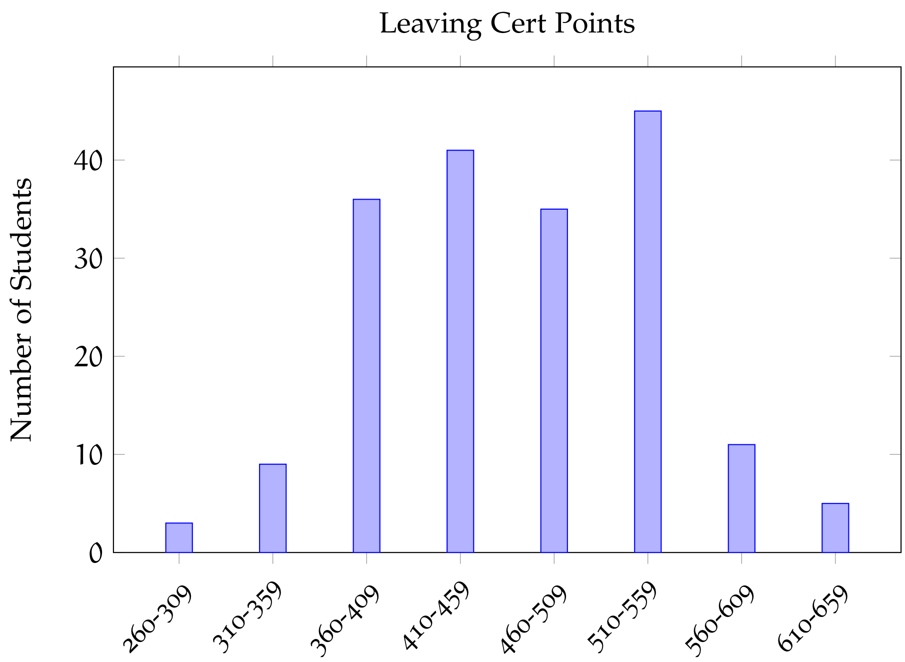

Figure 5.7: Distribution of Leaving Cert Points among Students

5.3.4 COLLABORATIVE WORKING HISTORY

Past Experience With Study Groups

Figure 5.8 presents and shows that 38.6% participants having prior experience in collaborative learning and 61.4% participants being novices, due to this collaborative learning dynamics can exhibit a spectrum of approaches. Those who have participated in collaborative learning previously, as illustrated in Figure 5.9, predominantly found it beneficial. They could be more likely to advocate for and drive effective collaborative strategies and share prior successes and pitfalls. In contrast, the majority who have not previously engaged might initially be hesitant or unsure of how to contribute. However, they bring fresh perspectives and approaches, which can be instrumental in diversifying the group's problem-solving methods.

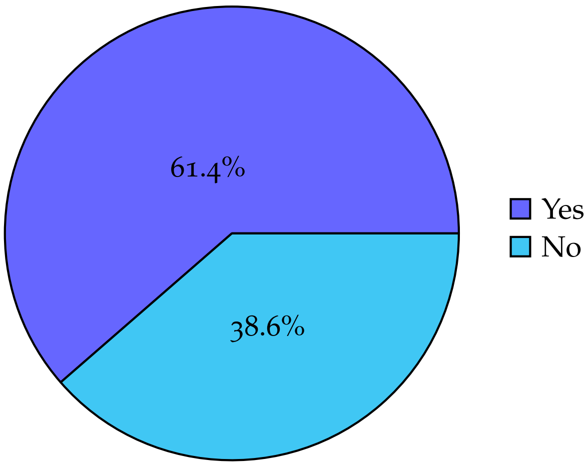

Figure 5.8: Have you previously taken part in collaborative learning?

5.3.5 SESSION FEEDBACK

As our session progressed we had some students participate in our session survey's who did not take part in the introductory survey. We have discounted their figures as we are unable to confidently track their results each week.

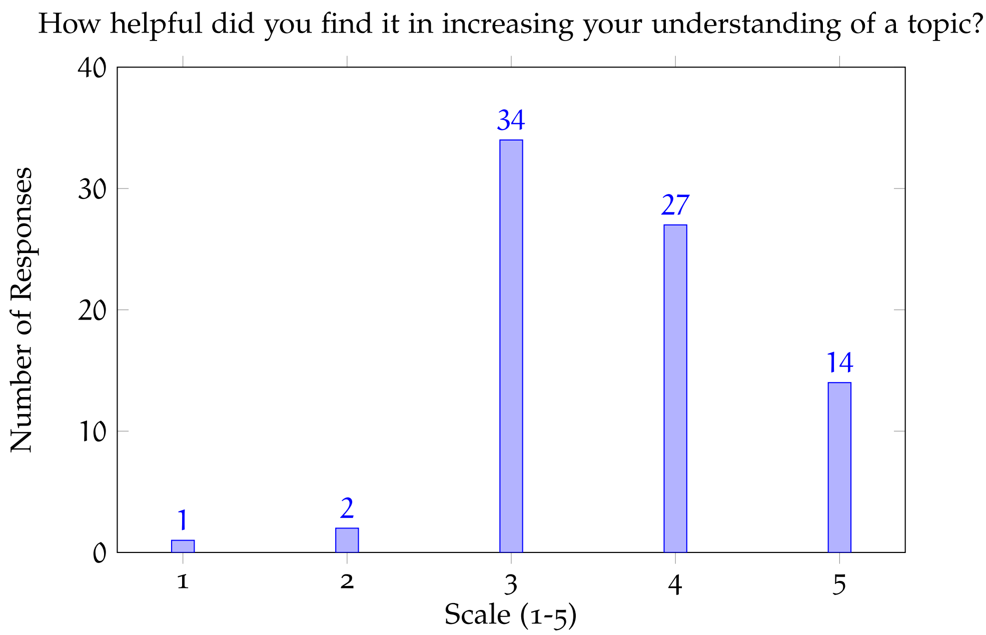

Figure 5.9: Collaborative Learning Effect on Understanding of a Topic

What we present next focuses on the results of the students who did participate in our survey each week as documented in Table 5.1.

Session Survey

Our session survey seen in Section 3.3.3 was designed to gather data on student's perception of the collaborative work sessions as well as their perception of their own work. This data could then be used to measure the impact of collaborative work week to week on the students. We surveyed opinions of both the individual and group work to examine if self-study preceding a CLS can enhance the experience.

- Q1: How helpful did you find the 30 minute session? [This was a scale of 1 to 10]
- Q2: Did you have a preference between working on your own or within a group?
- Q3: How helpful was the individual work for gaining a better understanding of the question? [This was a scale of 1 to 10]

- Q4: How helpful was the group work for gaining a better understanding of the question? On a scale of 1 to 10

High-level Overview

Table 5.2 presents the average response of students to the collaborative learning sessions week by week. From a broad perspective, the feedback is predominantly positive throughout the sessions. Session 1, focusing on "Strings," received the most favourable response with an average score of 6.825 out of 10. It is noteworthy that this session also had the highest number of participants, with 160 students engaging. This could indicate a greater interest or perhaps a a higher understanding of the topic as Strings had been introduced at a lower level to the class in the previous semester leading to a broader audience and more engagement.

The following session on "Sorting Algorithms" experienced a slight dip in both survey participation and average score, with 100 students yielding an average rating of 6.257. Sorting algorithms, being a more complex topic compared to strings, might have presented students with a more challenging learning experience.

Session 3, looking into "Classes and Objects," witnessed further reductions in both participation and average score, obtaining an average of 6.1 with 53 students. While the topic is fundamental in object-oriented programming, it can be abstract for some students, possibly leading to the slightly reduced score. This session taking place after a midterm break could be a factor in the reduction in survey participation as students felt less motivated after returning from break.

The final session on "Inheritance and Abstraction" saw a rebound in the average score to 6.314 but had the lowest participation of 32 students. Inheritance and abstraction are advanced concepts, and their perceived complexity might have dissuaded some students on the impact of the CLS. However, those who did participate in our survey found the session relatively more valuable than the previous one, as the uptick in the average score suggests.

In summation, while the sessions maintained a generally positive reception, there is a discernible trend of decreasing participation. The complexities of each topic and their sequential arrangement could have influenced this. The fluctuating average scores could reflect the varying degrees of difficulty and student familiarity with the respective subjects.

	Average of all students
Session 1	6.825 (n = 141)
Session 2	6.257 (n = 100)
Session 3	6.1 (n = 53)
Session 4	6.314 (n = 32)

Table 5.2: Average response to collaborative learning sessions week to week

5.3.6 in-depth overview

The comprehensive breakdown, as depicted in Table 5.3, allows for a deeper dive into the feedback across various demographic groups.

Across the board, for most sessions, male respondents have consistently scored the sessions slightly higher compared to their female counterparts. This trend is particularly evident in Sessions 1, 2, and 4. It is crucial to approach these results with caution, keeping in mind that individual learning experiences can be subjective and influenced by multiple factors and keeping in mind the variation of the group sizes for each session. Its been examined that while male participants have greater confidence in verbalising their ideas and suggestions Sander and Fuente [36].Female students have academic confidence in Studying and attendance Sander and Fuente [36]. It is important to keep this in mind as the methodology develops.

The Non-binary group, although showing fluctuations across the sessions, reveals an interesting pattern. Their score drastically reduced in Session 3, which centred around "Classes and Objects." This steep decline might indicate challenges faced by this particular demographic in comprehending the topic or perhaps external factors influencing their feedback for that session. However, given the smaller sample size of the Non-binary group, it is paramount to treat this data with caution. Any conclusions drawn from such a limited data set may not represent the broader experiences of this demographic.

The "Prefer not to say" category is nearly negligible in terms of results due to the extremely small sample size. For instance, there is only one respondent for Sessions 1 and 3, and no data for Sessions 2 and 4. Consequently, while the scores seem extremely high for this category, it is not prudent to derive any substantive conclusions.

A comparison between Rural and Urban respondents shows a slightly higher inclination towards the sessions from the Urban demographic, particularly for Sessions 1 and 4. Rural students might face challenges like limited access to resources or peers for group studies, potentially impacting their collaborative learning experience. The subtle differences in scores might hint at these underlying factors.

Both first-generation college students (FGCS) and non-first generation college students (NFGCS) showed close averages across all sessions. FGCS seemed to slightly prefer the session on "Classes and Objects" compared to NFGCS. Being the first in their families to attend university, FGCS might have distinct experiences and expectations from collaborative learning. Their unique background can both be an asset, bringing diverse perspectives, or a challenge if they feel unprepared or unsupported in collaborative tasks.

Different degree students showed varied preferences, indicating the relevance or appeal of certain topics to their academic background. The diverse academic backgrounds might affect the dynamics of collaborative learning. For instance, a student from an "Arts" background might approach a problem differently than a student from a "Science" background. While this diversity can lead to rich discussions and diverse problem-solving approaches, it can also result in potential misunderstandings or disagreements.

In summary, while broad patterns can be discerned from the data, the diversity in student backgrounds, academic inclinations, and individual learning experiences add layers of complexity. These factors can have pronounced implications for collaborative learning tasks, influencing both the dynamics and outcomes. Future analyses could delve deeper into these individualistic patterns, coupled with qualitative feedback.

5.4 LESSONS LEARNED FROM THE PILOT STUDY

5.4.1 TIMING

When conducting our collaborative sessions we observed the importance of keeping a clear time schedule, as detailed in Figure 3.2. As discussed in 3.2.2 we gave students 5 minutes of personal study time to look over the question and the notes. This was followed by 25 minutes of collaborative activity. It was key to give students there own personal time to familiarise themselves with the question as it lead to more interaction within the group work. In future studies this timing will be adjusted to allow 10 minutes of personal time and 20 minutes of collaborative to ensure students are able to make the most of their CLS. We believe that this additional personal time will also aid with questions that have a higher level of complexity giving more time for understanding the specifics and topic of the task.

5.4.2 ENGAGEMENT

While we found 100% engagement from students in the collaborative learning task, excluding students who arrived late or did not turn up for their session, we observed a degradation in participation with the follow up surveys. In future studies we will provide additional reminders to participants to complete the surveys as soon as they can following the session.

5.5 CONCLUSIONS

The objective of this pilot study was to create a solid foundation for our collaborative methodology fundamentals, by testing the methodology in an offline setting. We also began addressing the question "Does engaging in a study group foster a greater interest in a subject?". By analysing the effectiveness and reception of CLS among our participants, this study sought to figure out if the created methodology for group study could enhance interest and engagement in the given subject.

Over four Collaborative learning sessions, various degrees of participation and scores of session evaluation were observed. These patterns indicated that both the complexity of the topic and the way in which they were presented could influence student participation, feedback, and potentially, their interest.

The demographic data revealed insightful patterns. Although we do need to take into consideration that over half of students came from and Urban upbringing and over half of students were male. We found male respondents, on average, rated the sessions higher than their female counterparts. Urban and rural participants displayed different feedback patterns, suggesting that factors like accessibility to resources might influence the effectiveness of collaborative learning and, consequently, interest in the subject. The difference in feedback between first-generation college students and others brought to light the diverse challenges and assets these students bring to a collaborative learning environment.

We observed that timing of the sessions played a pivotal role in student engagement. Providing students with more personal study time led to better preparation and more fruitful collaborative interactions, suggesting that a balance between individual study and group engagement might be key to fostering interest. A noted challenge was the declining participation in follow-up surveys, indicating a need to ensure more robust feedback collection mechanisms.

While the pilot study presented predominantly positive feedback, it highlights the importance of understanding students' diverse needs, backgrounds, and learning styles when determining the impact of group study on subject interest. The findings point towards the potential benefits of collaborative learning in fostering interest in subjects, but they also highlight areas of refinement. As the methodology for CLS evolves into a hybrid and online setting, it is crucial to continue refining the approach and to cater to a diverse student populace and more definitively answer the core research question.

Demographic	Session 1 Average (n=141)	Session 2 Average (n=100)	Session 3 Average (n=53)	Session 4 Average (n=32)
Male	7.08 (n=87)	6.5 (n=70)	6.242 (n=33)	6.55 (n=21)
Female	6.46 (n=50)	5.885 (n=26)	6.5 (n=16)	5.778 (n=9)
Non-binary	6.667 (n=3)	5.5 (n=4)	3.667 (n=3)	5.5 (n=2)
Prefer not to say	9 (n=1)	N/A	8 (n=1)	N/A
Rural	6.56 (n=50)	6 (n=39)	6.0455 (n=22)	5.588 (n=17)
Urban	7.033 (n=91)	6.492 (n=61)	6.323 (n=31)	7.071 (n=15)
FGCS	6.846 (n=65)	6.313 (n=48)	6.571 (n=21)	5.857 (n=15)
NFGCS	6.882 (n=76)	6.2885 (n=52)	5.969 (n=32)	6.588 (n=17)
BA Arts	6.357 (n=28)	6.095 (n=21)	6.167 (n=6)	7.5 (n=2)
BSc Science	6.44 (n=36)	5.619 (n=21)	7 (n=9)	5.6 (n=6)
BSc Comp. Sci. & Soft. Eng.	6.852 (n=27)	6.462 (n=13)	5.615 (n=13)	5.6 (n=5)

FGCS = First generation college student, NFGCS = Non-first generation college student

Table 5.3: Session Evaluation Demographic Breakdown

6 CS620C STUDY

6.1 Introduction

Our study took place in September 2022 within the CS620C module as described in Section 1.6.2. This module is an accelerated 3 week pre-semester course that deviates from the traditional academic semester but incorporates much of the topics usually covered across both CS161 (see Section 1.6.2) and CS162 (see Section1.6.2).

This module is offered as part of a number of Higher diploma courses within the Computer Science and Mathematics department's. Due to this all students have completed a prior bachelors degree and many participants have been working in various industries for a number of years. This provides us with a very diverse group of participants which encourages many different perspectives.

Due to its accelerated nature we conducted our experiment over two weeks of the three weeks of the module and hosted 9 Collaborative learning sessions. Unfortunately an error was made during our data collection were we mistakenly anonymised the data upon submission rather than during our data cleansing phase which protects our participants data while still letting us connect participants through multiple surveys. Due to this our quantitative results proved to be inconclusive but we will still present our qualitative results which were instrumental in helping refine the methodology and the development of the web and mobile application.

6.2 CS620C GROUP

6.2.1 TIMELINE

The structure of the course was as follows: Monday to Thursday students would have lectures on one topic and then complete a programming lab based on the topic of the day. On Friday they would have an exam. Due to this we managed to run four sessions per week for two weeks along with an introductory session. All of these sessions were conducted in a simulated online environment.

Table 6.1 presents a timeline describing the topic covered each week, along with the number of participants surveyed. The total size of the class was n=18. Week to week we saw a significant proportion of participants take part in the survey. However it is noticeable that for session 8 and 9 had a downturn in survey submission this could be due to a number of factors influencing the decline in survey participation, including fluctuating class attendance, the rising complexity of the posed questions, and potential overlapping commitments of the students during the final week.

Table 6.1: Timeline - Topic covered each week

Week	Date	Topic	Participants
1	September 1st	Conditionals	15
2	September 5th	Iterators	18
3	September 6th	Strings	12
4	September 7th	User Input	13
5	September 8th	Arrays	11
6	September 12th	2D Arrays	10
7	September 13th	Methods	15
8	September 14th	Classes and Objects	6
9	September 15th	Inheritance	7

6.2.2 web application

As discussed in Section 4.5.1 the first version of our web app was trialled in this study. This web application features a simple but clear user interface as seen in Appendix **??** where we could separate our cohort into groups of four and have a simulated online CLS. We define our simulated online sessions as sessions that took place within our face-to-face laboratories but all communication takes place through the web application. Our students were paired up randomly prior to the group collaboration section beginning and would be informed of their group at the beginning of their 30 minute session. This was to discourage vocal communication prior to the session. We did this to reduce potential distractions from students engaging in person rather than online.

Within the web application, students could communicate via text and send pieces of code or pseudo code between the group to help form a consensus on the solution to the task. Throughout the nine sessions we gathered both vocal and written feedback on features and updates to be added to future versions of the application and this is discussed in Section 6.3.2.

Overall, after this version of the application gained positive feedback and uncovered some unforeseen technical issues in our system. These issues included a server resource issue that became apparent with a large amount of first time registrations. Fortunately such issues had quick solutions such as scaling up Heroku resources and had little to no impact on the session.

6.2.3 participants

Our second study took place with a diverse selection of students. From our introductory survey we were able to collate the diverse demographics that made up our cohort. These findings are laid out in Table 6.2. Out of our class of 18 students 15 took part in this survey giving us the ability to plot out the background of the type of students taking this course.

When exploring their academic background, the majority, 11 participants, were enrolled in an HDIP Software Development course. A single participant was from the HDIP Human Computer Interaction course, while 3 were from the HDIP Data Analytics course.

With respect to generational academic advancement, more than half (8 out of 15) identified as first-generation college students, suggesting they were the first in their immediate family to attend a college or university. Additionally, a larger proportion of the participants came from a rural background (10 participants), compared to 5 participants from urban settings. The Leaving Certificate, was taken by 12 participants, while 3 followed an alternative academic pathway. The distribution of points achieved in the Leaving Certificate among the students portrayed in Figure 6.1, showcases a wide range of points, indicating diverse academic capabilities and achievements.

In terms of age, there was a broad spectrum, ranging from early twenties to mid-fifties. The age distribution is illustrated in Figure 6.2, which highlights that our study attracted not only fresh graduates but also professionals and individuals seeking further education later in life.

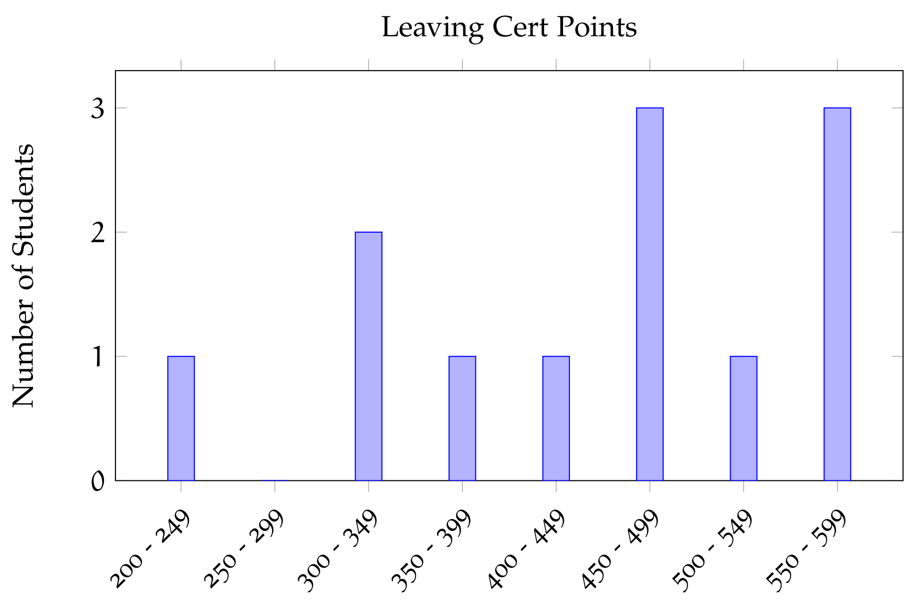

Figure 6.1: Distribution of Leaving Cert Points among Students

Table 6.2: CS620C Study Demographic Breakdown

	Demographic	N
Gender		
	Male	13
	Female	2
College Course		
	HDIP Software Development	11
	HDIP Human Computer Interaction	1
	HDIP Data Analytics	3
Are you a first generation college student?		
	Yes	8
	No	7
Are you form a rural or urban background?		
	Rural	10
	Urban	5
Did you sit the Leaving Certificate?		
	Yes	12
	No	3

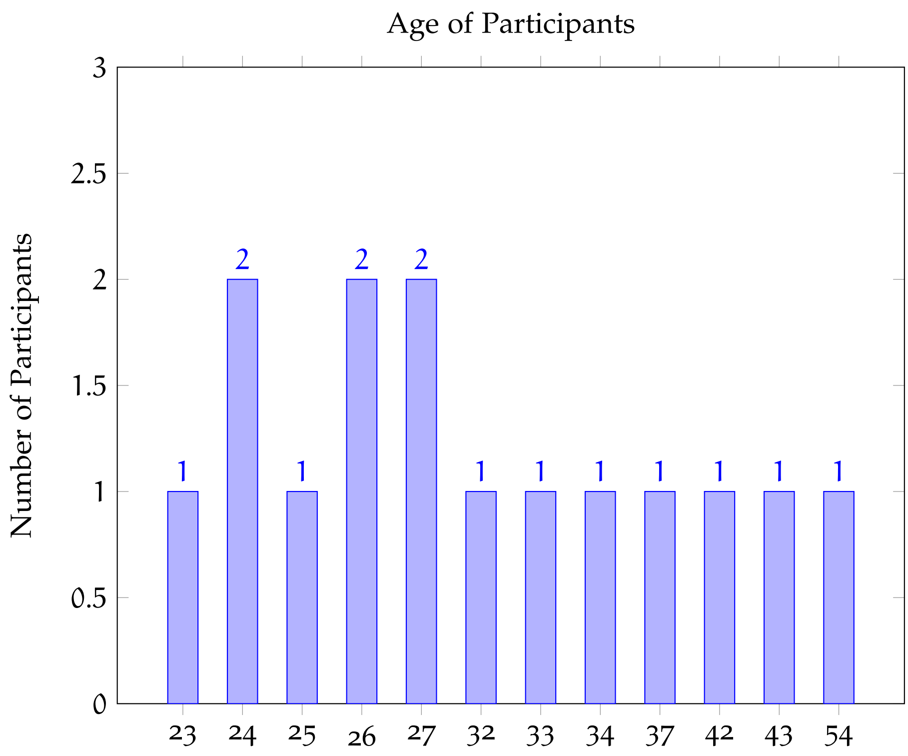

Figure 6.2: Age distribution of participants.

6.3 RESULTS

6.3.1 SESSION FEEDBACK

Our surveys were the same as our first study and can be seen in Sections 5.3.1 and 3.3.3 but for this study we also included a feedback section at the end of our session surveys.

Our new survey followed the following format:

- Q1: How helpful did you find the 30 minute session? [This was a scale of 1 to 10]
- Q2: Did you have a preference between working on your own or within a group?
- Q3: How helpful was the individual work for gaining a better understanding of the question? [This was a scale of 1 to 10]

- Q4: How helpful was the group work for gaining a better understanding of the question? [This was a scale of 1 to 10]

- Q5: Do you have any further comments or suggestions about the session?

Due to our mistake regarding participant anonymisation, as discussed in Section 6.2, we are unable to draw in-depth conclusions on the progress of our participants from week to week. We can however display our overall data regarding participant preference from week to week as well as the overall average perception of our participants. Figure 6.3 and Figure 6.4 show that our cohort for most weeks found the group work more beneficial than the personal excluding session 2 and session 5 which focused on the topics of iterators and arrays. Factors influencing this could be that both concepts can be difficult to visualise upon first learning. This could have pushed students to want more personal time to understand the task before approaching it from a group perspective. We can see that even in these weeks our average response to the sessions were quite high and students still felt there was a lot to be gained from the sessions.

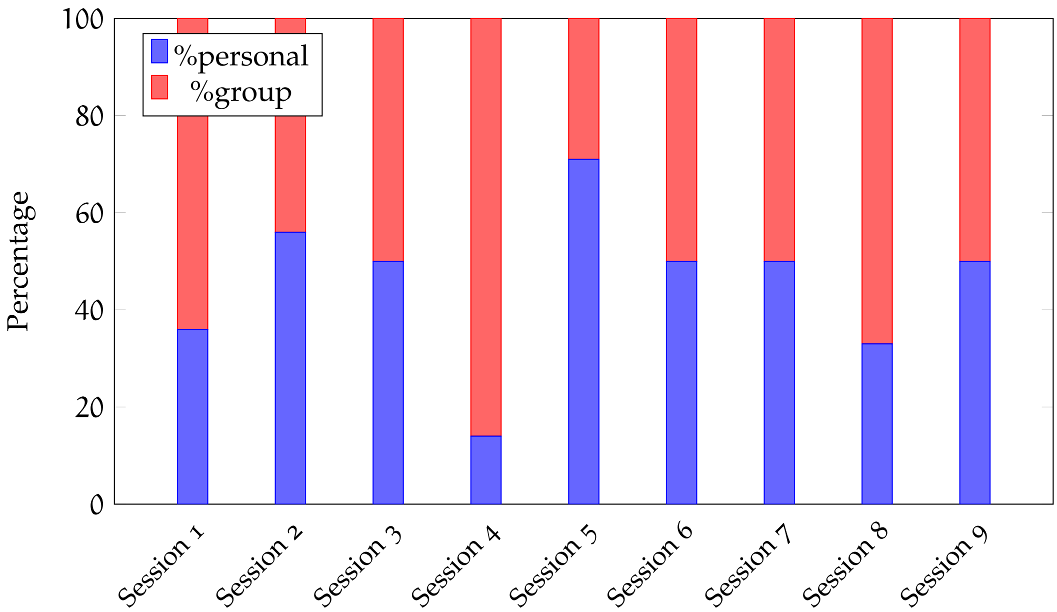

Figure 6.3: Distribution of Personal vs. Group preferences across Sessions

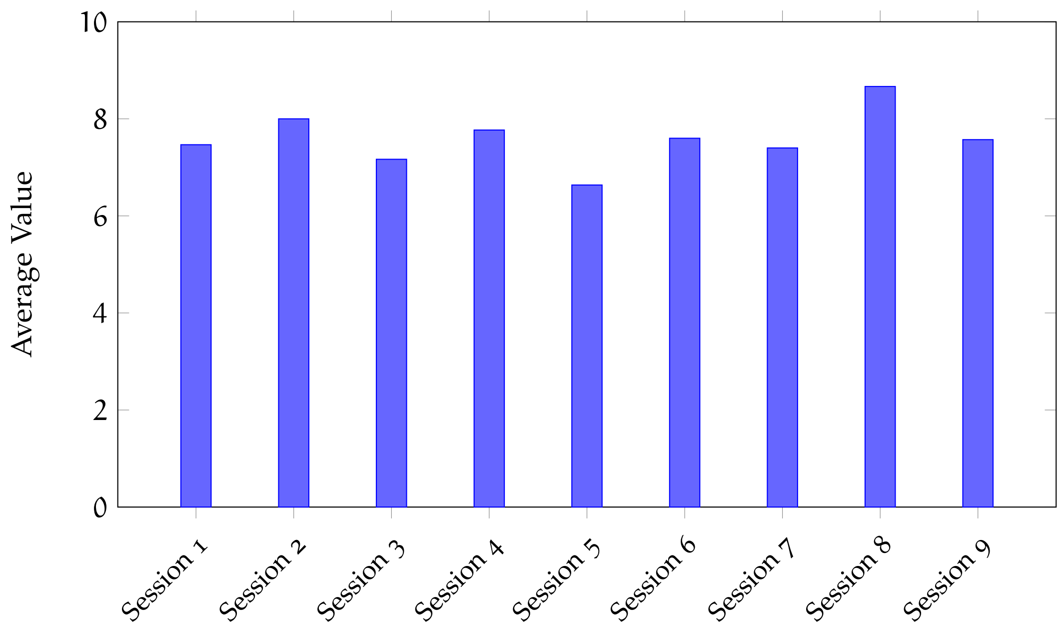

Figure 6.4: Average response to How helpful did you find the 30 minute session?

6.3.2 survey written feedback

The written feedback received was very encouraging and students requested a large amount of features that we had already planned to integrate with the next version of the app.

The feedback we received from our users has been instrumental in shaping the next iteration of our application. We were encouraged by the positive reception and active engagement of the users with our platform. Notably, a majority of the feature requests align with our envisioned enhancements for the upcoming release, validating our developmental direction and reaffirming the need for such features in a successful collaborative learning platform.

Below is a representative sample of the feedback we received with a focus on comments related to changes to the session and those relevant to our research questions.

- "The session was great, but it'd be nice if we could share photos directly in the chat."

- "Loved the group work!, great way to find out new things."
- "It would be so much easier if there was a way to share code-live. Rather than copy and pasting."
- "It was decent for our group study, but it got a bit chaotic with everyone typing and sharing links. Maybe adding a feature to keep track of and compile notes would be super helpful?"
- "I felt the platform was a bit basic."
- "The interface was user friendly"
- "I wish there was a way to sort our chat into topics or threads. It got a bit confusing trying to follow multiple conversations at once."
- "The collaborative learning was great, really helped get a different perspective but I wish we had more time."
- "Honestly, a feature to conduct quick polls or votes would be beneficial, especially when we're trying to come to a consensus."

From our feedback it is pertinent that a diverse cohort can be helpful to creating a positive experience when using our platform. Having various demographics and life experiences can provide alternate viewpoints and encourage different ways of thinking about a task. We have also observed the impact collaborative learning can have where students are exposed to new ideas and discovering new ways to tackle problems this can impact not only their understanding but their interest in the topic.

6.4 Lessons learned from the CS620C study

6.4.1 Data organisation

After realising our error in setting up our data collection we put in place procedures to ensure that this would not occur again.

6.4.2 application features

A list of essential and desirable features as seen in Table 4.1 was collated from both our own observations and the written feedback collected throughout this study 6.3.2. These features will be taken into account when designing our second version of the application as well as our mobile application. This should ensure a more effective experience for participants using the platform.

6.4.3 conclusion

This chapter provided a comprehensive examination of the CS620C study, revealing crucial insights and lessons to further the aims of our research. The study's distinct environment, set within the accelerated three-week module of CS620C, offered both challenges and opportunities. Due to the module's intensive nature, we observed a diverse group of participants with a broad spectrum of backgrounds, both academically and professionally. This diversity is believed to have enhanced the collaborative learning sessions, enabling multiple perspectives and experiences to merge.

While the unfortunate error in data anonymisation limited the depth of our quantitative results, it also provided an essential lesson in procedural rigour and data management. Despite this, the qualitative feedback proved invaluable to identifying which functionality needed to be further developed for the next version of our application. The responses underscored the impact of collaborative learning, showcasing how group dynamics can deepen understanding and amplify interest in the subject.

While challenges arose, they have paved the way for significant improvements. The feedback on the initial web application version highlighted both its strengths and areas for improvement. By aligning this feedback with our development roadmap, we are reassured of the direction in which we were heading.

7

YEAR LONG STUDY

7.1 INTRODUCTION

The study documented in this chapter took place over two academic semesters, encompassing one academic year. The students participating in this study were from the CS161 (see Section 1.6.2) and CS162 (see Section 1.6.2) modules. This study was our most significant so far, with n=232 participants taking part in our introduction survey. With a large participant population, we decided to split the population into two distinct groups and run two scenarios side by side: an Offline group (Group 1) and an Online group (Group 2). We strategically selected our groups based on two primary criteria: Proximity and a deliberate effort to maintain a balanced demographic representation within each group. A breakdown of this data can be seen in Section 7.3.5. Within this study, four laboratories a week were run to provide adequate space within Maynooth University's facilities; this allowed us to place two laboratories into each group. Besides this, the activity variables remained the same. All tasks asked in the CLS were of the same level of difficulty, and each group followed the same time constraints for both personal and group work.

What changed between the groups was that Group 2 used a mix of the web application version 2 and the mobile application to complete their sessions. At the same time, Group 1 followed a similar format to that of our pilot study. We assessed engagement within the groups using the same two surveys as used previously (see Section 5.1). However, we introduced a new variable, "Did you participate in an offline or online session?" to distinguish between the data collected from each group more clearly.

7.2 YEAR LONG GROUP

7.2.1 TIMELINE

Our year-long study occurred during the 2022/2023 academic year; within this time frame, we held twelve collaborative learning sessions, seven in the first semester and five in the second as seen in Table 7.1 and Table 7.2. In our first semester, we held a session each week with both of our groups. In the second semester, we focused on our online group to better understand the effect of online learning as a collaborative learning tool.

Table 7.1: Timeline first semester - Topic covered each week

Week	Date	Topic	Participants
1	October 13th	Variables	80
2	October 20th	Conditionals	95
3	October 27th	Iteration	115
4	November 10th	Strings	96
5	November 17th	User Input	85
6	November 24th	Numbering Systems	81
7	December 1st	Arrays	69

Table 7.2: Timeline second semester - Topic covered each week

Week	Date	Topic	Participants
1	February 23rd	Methods I	33
2	March 2nd	Methods II	29
3	March 9th	Regular Expressions	30
4	March 23rd	Recursion	27
5	March 30th	Classes and Objects	18

7.2.2 WEB APPLICATION

The web application as described in Section 4.5 was the second version of our web application for the evolution of this application (see Section 4.5.2). We utilised this version in the study as it had the same functionalities as our mobile application. This was particularly important for students who were unable to access the mobile application due phone incompatibility.

7.2.3 MOBILE APPLICATION

This was the first study where we deployed the mobile application giving students more opportunity and flexibility with our platform. The development of this application is described in Section 4.6.

7.2.4 PARTICIPANTS

Our cohort for this study consisted of students from the CS161 and CS162 modules across the 2022-2023 academic year. With our previous successful implementations across the introductory computer science modules, we once again partnered with Maynooth University's computer science faculty.

Within this study, we wanted to observe how students progressed from minor to no programming skills to gain foundational skills. The laboratories followed the same format as our previous two studies but with the difference of introducing online collaborative elements as discussed in Section 7.1.

In our first session, we again surveyed the cohort with our introductory survey. This survey focused on collating demographic and background data on the participants as discussed in Section 7.3.1. From this, we gathered feedback from 232 participants. It is important to note that the total course size was 570 students. Nevertheless, a large sample of 232 will give an accurate reflection of the cohort within the introductory session and the follow-up sessions, even as engagement with the survey fluctuates each week.

7.3 RESULTS

7.3.1 INTRODUCTION SURVEY

The introduction survey was kept the same as the past two studies, the format of which can be seen in Section 5.3.1. As discussed in our Section 7.1 The introductory survey was carried out once in our first collaborative session. The survey focused on three key areas: Individual Background, Educational Background and Collaborative Working History, which are detailed in Section 7.3.2, Section 7.3.3 and Section 7.3.4. Using the responses from each of our areas, we were able to group our students into clusters and analyse how their experience was affected within the CLS's - this is discussed further in Section 7.3.6 and Section 7.3.8.

7.3.2 INDIVIDUAL BACKGROUND

The individual background section provides insights into the personal characteristics of our participants. It allows us to comprehend the diversity and various elements the students bring into the learning environment. Understanding the individual background is essential as it can influence the learning experiences, preferences, and challenges the students face.

Age

In this section, we look into the age distribution, which is one of the primary demographic factors, shedding light on the age profile of our cohort and the implications it might have on their collaborative learning activities.

From Figure 7.1, we can observe that the age profile of the demographic skews predominantly towards a younger demographic. A significant majority, 83% (193), are between the ages of 17 and 19. This range aligns with the typical age bracket of first-year university students. However, it is worth noting that the sample does include a broader age range, extending up to 32 years old. This suggests a diversity in the age of students enrolling in introductory

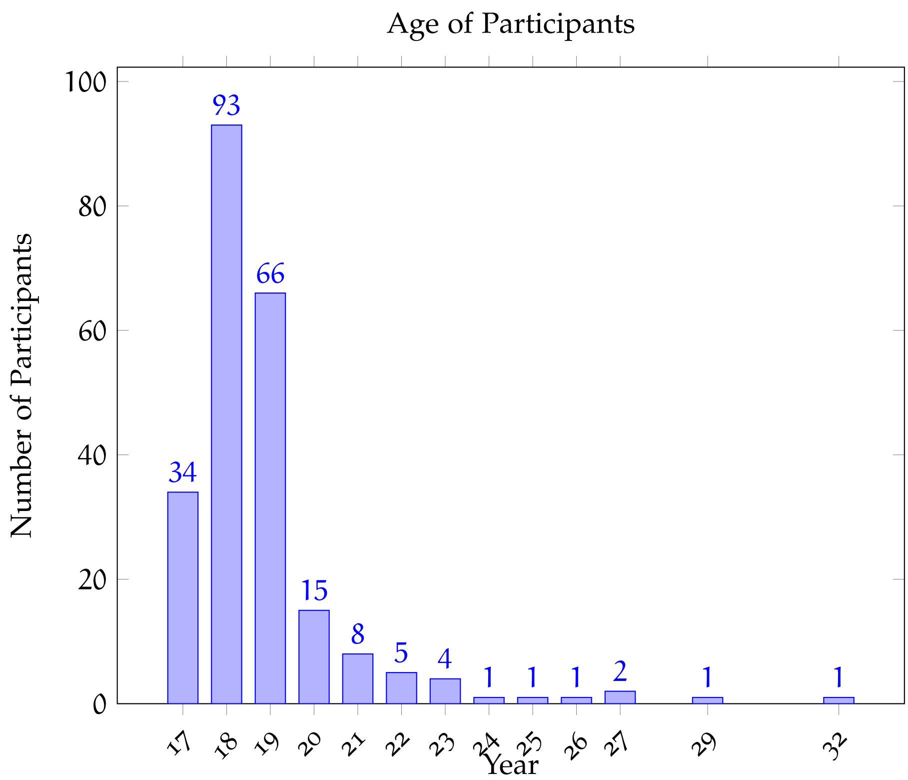

Figure 7.1: Age distribution of participants.

computer science classes at Maynooth University, possibly including mature students or those who have taken gap years or pursued alternative educational paths before enrolling in the university. This age diversity could bring different perspectives and experiences into the learning environment.

Gender

As evident in Figure 7.2, the large majority of participants identify as Male, constituting 69% (160) of the sample. Students that identify as Female make up 26.7% (62) of the cohort, while the the rest of the participants either identify as Non-binary 1.7% (4) or prefer not to specify their gender 2.6% (6). This gender distribution is noteworthy as it highlights the gender disparity in introductory computer science classes. It also highlights the importance of considering gender dynamics when designing and implementing collaborative learning activities, ensuring that the activities are inclusive and conducive to all participants regardless of gender identity.

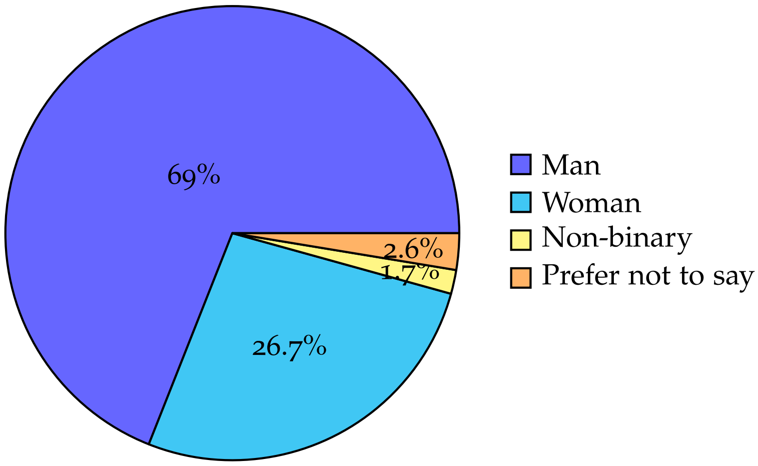

Figure 7.2: Gender distribution of participants.

Environmental Background

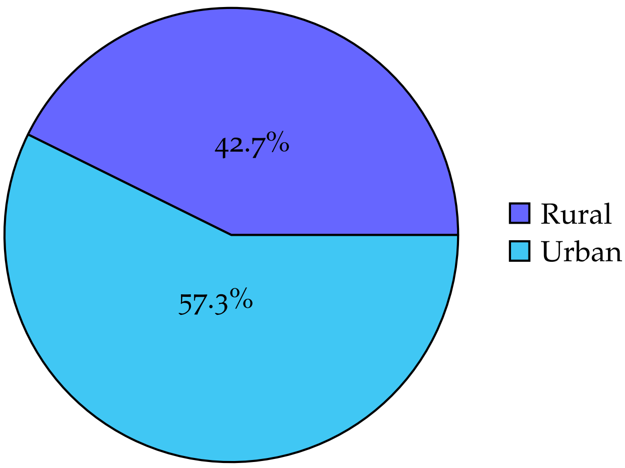

Figure 7.3: Environmental upbringing distribution of participants.

In Figure 7.3, it is discernible that a slight majority of our participants, 57.3% (133) come from an urban background, while 42.7% (99) come from a rural setting. This distribution offers a balanced view of the student's geographical upbringing, reflecting a near-equal representation from both urban and rural areas. Such diversity in environmental backgrounds could have been affected by the participants' prior experiences, access to resources, and social experiences, influencing their approach and receptivity to collaborative learning activities. Acknowledging this diversity, it is essential that we consistently enable our students to participate equally in our collaborative learning sessions.

7.3.3 EDUCATIONAL BACKGROUND

The educational background of participants showcases the differing past and current academic paths and experiences of our participants. In this section, we will explore the various college courses that the participants are currently enrolled in, highlighting the academic disciplines that are most represented among the cohort. As well as examining the past academic history of the cohort by means of their points received in the leaving certificate. A clearer understanding of their educational background not only gives context to their existing knowledge and skills but also offers insights into the potential interdisciplinary strengths and challenges present within the collaborative learning environment.

College Course

Figure 7.4 describes the variance in college courses present in the CS161 and CS162 modules. It is important to note that these modules are mandatory for the BSc Computer Science and Software Engineering, BSc Robotics & Intelligent Devices, and BSc Multimedia & Web Development courses. This chart highlights the prominence of students from BSc Computer Science and Software Engineering as well as Maynooth University's two general entry courses, Bachelor of Science and Bachelor of Arts. The "Bachelor Of Science" and "BSc Computer Science & Software Engineering" courses have an equal representation, each having 58 participants. This is closely followed by "Bachelor of Arts" with 57 participants. Such a significant number of participants from these disciplines signifies the nature of the module – being an introductory computer science class, it naturally attracts a substantial number of students from closely related fields.

However, it is intriguing to note the presence of students from diverse disciplines such as "BA International Finance & Economics", "BSc Multimedia &

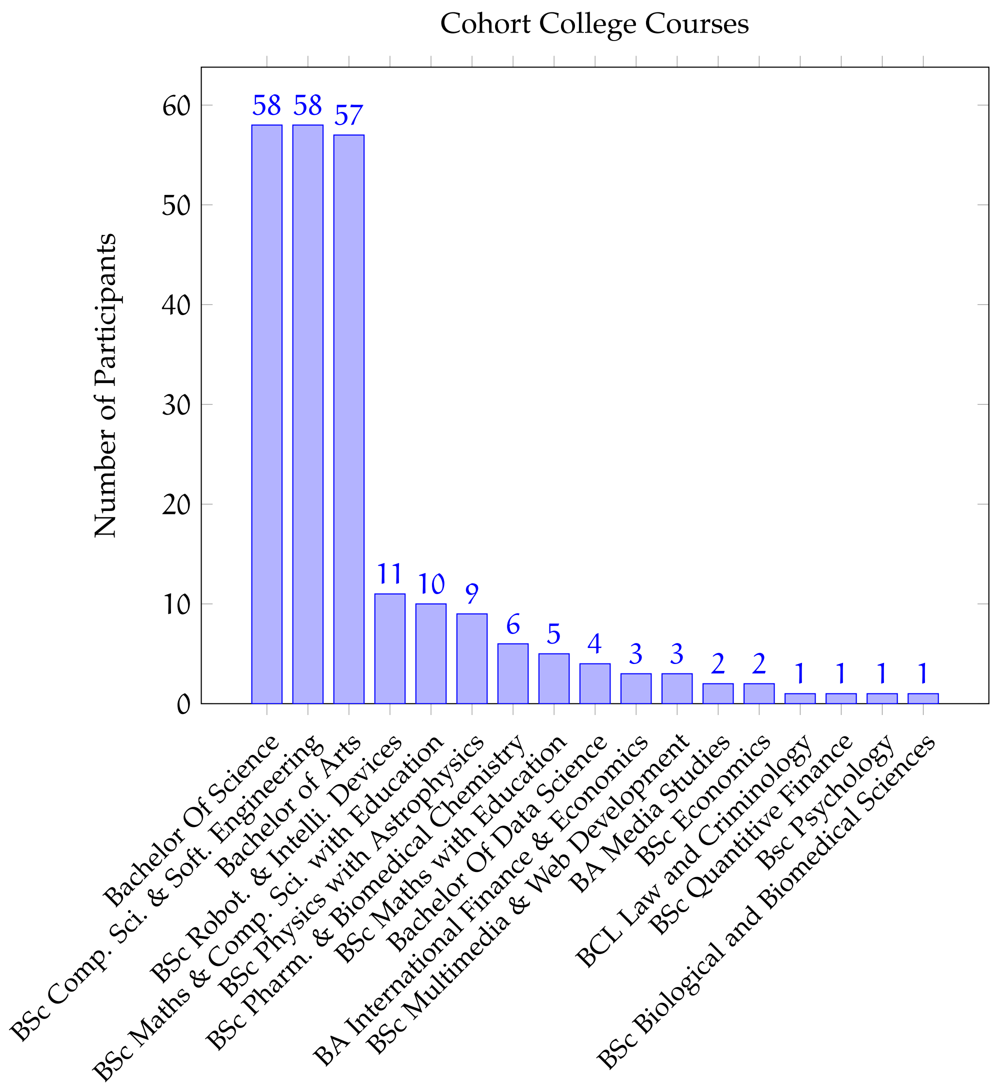

Figure 7.4: Cohort College Courses

Web Development", "BA Media Studies", and even "BCL Law and Criminology". Although these courses are less represented compared to the aforementioned major courses, their inclusion emphasises the interdisciplinary appeal of the module. These students, coming from varied academic backgrounds, bring unique perspectives to the collaborative learning environment, enhancing discussions with distinct knowledge and experiences. The minority courses, represented by a single participant each, such as "BSc Quantitive Finance", "BSc Psychology", "BSc Biological and Biomedical Sciences", and "BCL Law and Criminology", highlight broad enrollment of the module. It is open to many courses for students keen to try out computer science, irrespective of their primary academic discipline.

Parental Education

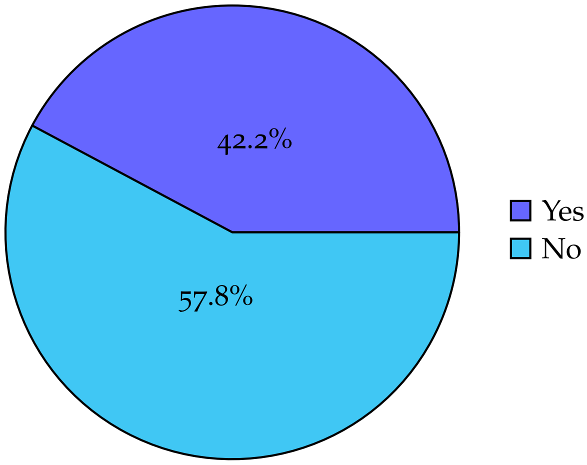

Figure 7.5: Are you a first-generation college student?

From Figure 7.5 we can observe that 42.2% of the 232 participants indicated that they are the first in their family to attend college, thus classifying them as first-generation college students. Conversely, 57.8% have had parents who have previously attended college. Recognising the different experiences and challenges that first-generation students might have had in developing collaborative learning skills is important for ensuring an inclusive and equitable learning environment.

Previous Academic Background

The academic backgrounds of students often give us a clearer insight into their prior educational experiences. As part of the survey, we investigated whether or not students had sat the Leaving Certificate examination and, if so, the points they had secured.

As seen in Figure 7.6, an overwhelming 92.2% (214) of the participants had taken the Leaving Certificate examination, while a small minority, 7.75% (18), had not. This reinforces the commonality of the Leaving Certificate as a prevalent pathway into higher education in Ireland. It is important to note that not

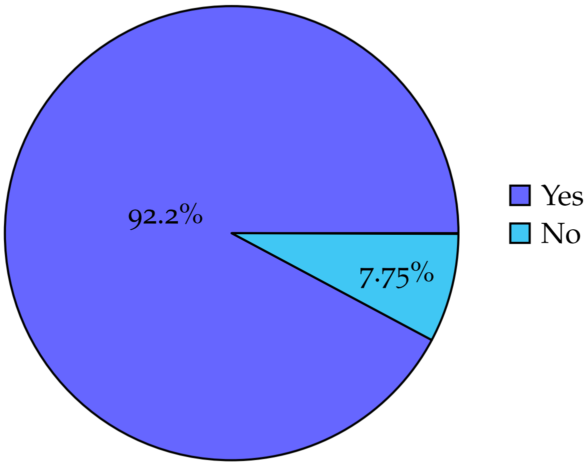

Figure 7.6: Did you sit the leaving cert?

all students who sat the Leaving Certificate used that purely as an entryway to university, which is why we also examined the points that which the 214 participants were awarded.

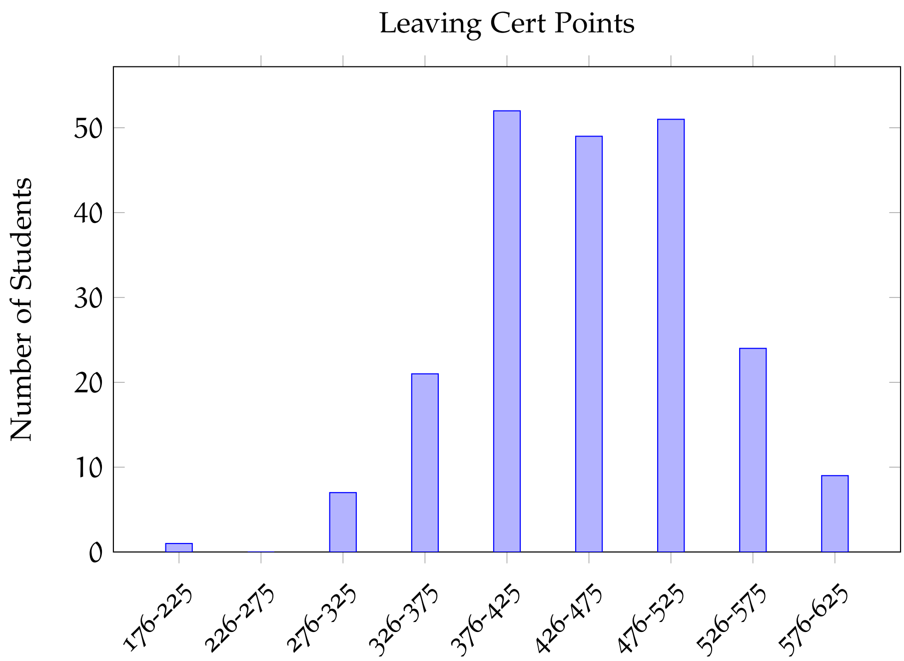

Figure 7.7: Distribution of Leaving Cert Points among Students

From Figure 7.7, the most frequently observed points brackets were between 376-525, each encapsulating a significant number of the student participants. These figures underline the competitive nature of entry into higher education courses, with many students achieving commendable results in their Leaving

Certificate exams. Some of our participants, even those who did take the Leaving Certificate, would utilise a non-traditional entryway to Maynooth University, and it is important that we provide adequate support to every student to ensure that they are able to collaborate effectively.

7.3.4 COLLABORATIVE WORKING HISTORY

Collaborative learning plays a key role in effective teaching, encouraging students to work together and share knowledge. This section looks at participants' past experiences with collaborative learning in study groups and their opinions on how it helped their understanding.

Past Experience With Study Groups

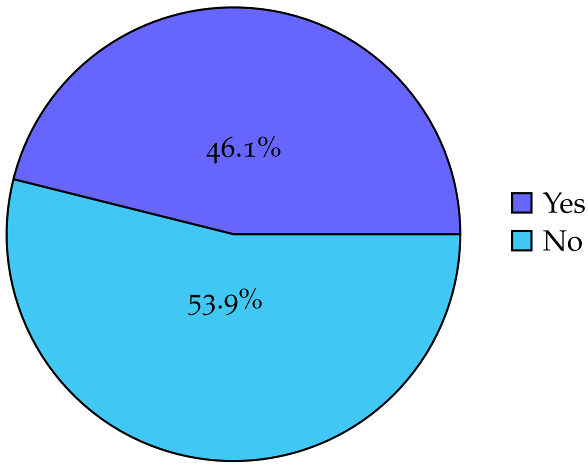

Figure 7.8: Have you previously taken part in collaborative learning?

The survey unveils in Figure 7.8, a fairly balanced distribution concerning prior experience in collaborative learning, with 46.1% of participants having experienced it and 53.9% not having done so. This disparity points towards varied educational experiences and learning methodologies that students have been exposed to before joining Maynooth University.

For those who have had such experiences, the next question aimed to determine how useful they found it in understanding a subject better.

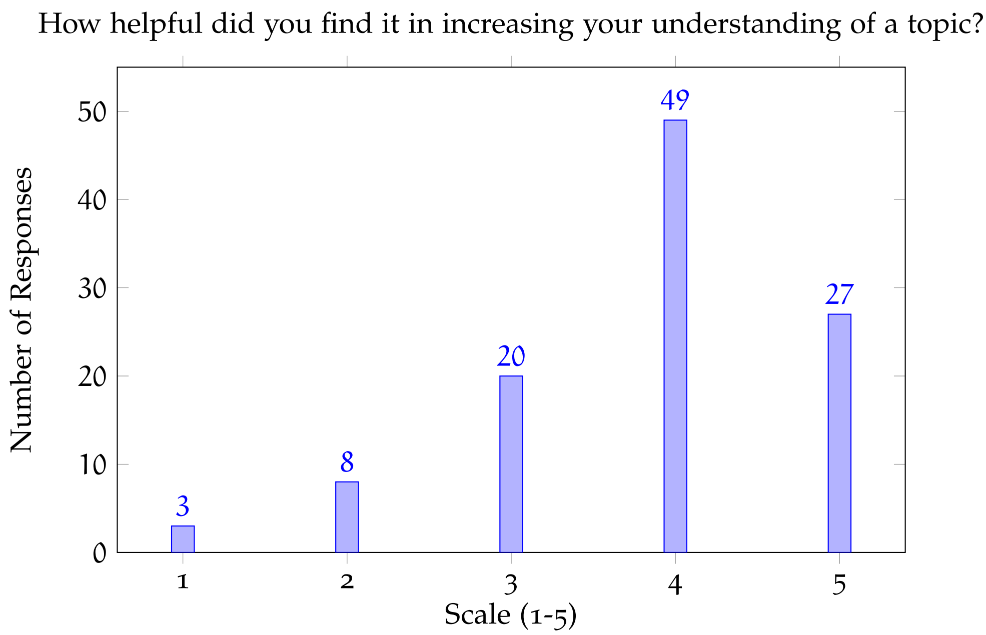

Figure 7.9: Collaborative Learning Effect on Understanding of a Topic

The data in Figure 7.9 indicates a strong inclination towards the positive side of the scale. A combined 76 respondents rated the efficacy of collaborative learning at 4 or 5 (out of 5). This strong positive feedback highlights how working collaboratively can help students understand their subjects better.

7.3.5 GROUP 1 AND GROUP 2

To provide a comprehensive understanding of the participant groups in this year-long study, we have differentiated them into two distinct categories: Group 1, which undertook offline sessions, and Group 2, which engaged in online sessions.

This subdivision was essential to assess the impact of offline versus online collaborative environments on student engagement and learning outcomes. With this in mind, the formation of these groups was done to ensure a near-proportional representation of various demographics, which is important to maintain diversity and inclusion. The demographic breakdown, as depicted in Table 7.3, highlights the similarities and subtle variances between the two groups.

The emphasis was not just on creating two separate environments for our study but ensuring that these environments are representative of the broader student population. The subsequent analyses in the later sections delve deeper into the experiences and responses of these two groups, providing invaluable insights into their dynamics, participation, and overall engagement with the Collaborative Learning Sessions (CLS).

Demographic	Group 1 (n=90)	Group 2 (n=142)
Male	72.2% (n=65)	66.9% (n=95)
Female	25.6% (n=23)	27.5% (n=39)
Non-binary	1.1% (n=1)	2.1% (n=3)
Prefer not to say	1.1% (n=1)	3.52% (n=5)
Rural	41.1% (n=37)	43.7% (n=62)
Urban	58.9% (n=53)	56.3% (n=80)
FGCS	45.6% (n=41)	40.1% (n=57)
NFGCS	54.4% (n=49)	59.9% (n=85)
BSc Science	33.3% (n=30)	19.7% (n=28)
BSc Comp. Sci. & Soft. Eng.	24.4% (n=22)	25.4% (n=36)
BA Arts	21.1% (n=19)	26.8% (n=38)
Other	21.2% (n=19)	28.1% (n=38)

FGCS = First generation college student, NFGCS = Non-first generation college student

Table 7.3: Session Evaluation Demographic Breakdown

7.3.6 First semester session feedback

Our Session survey as seen in Section 3.3.3 and Appendix **??** followed the same structure as the previous two studies. Due to the positive engagement in the summer study we kept our feedback section and utilised it to gather further feedback on the CLS's as the study progressed. We also included a short question at the start of the survey for students to check off if they took part in a online or offline study group this week. This acted as an extra variable allowing us to differentiate between the two groups feedback each week.

Our final survey follows the following structure:

- Q1: Did you complete an online or offline session this week?
- Q2: How helpful did you find the 30 minute session? [This was a scale of 1 to 10]
- Q3: Did you have a preference between working on your own or within a group?
- Q4: How helpful was the individual work for gaining a better understanding of the question? [This was a scale of 1 to 10]
- Q5: How helpful was the group work for gaining a better understanding of the question? [This was a scale of 1 to 10]
- Q6: Do you have any further comments or suggestions about the session?

Over the course of the first semester, we collected the data showcased in Table 7.4. This data was then further analysed to investigate how different demographics perceived the sessions from week to week. This is further discussed in Section 7.3.6.1, Section 7.3.6.2 and Section 7.3.6.3

Gender Analysis

The data displayed in Figure 7.10 and Figure 7.11 reveals interesting insights into the differences in session rankings across genders and between the two distinct methodologies: offline (G1) and online (G2).

For both males and females, Group 1 (G1) displayed greater variability in session rankings compared to Group 2 (G2). This variability in G1 might be attributed to the nuances of offline interactions. Factors such as peer interactions, the physical environment, and tangible activities can influence how a session is perceived.

In contrast, Group 2 (G2), which is online, manifests more consistency in session rankings. Particularly for females, there is a semblance of uniformity

Table 7.4: Average ranking of how helpful students found sessions by Demographic, Group, and Environment

	S1	S2	S3	S4	S5	S6	S7
G1 Male	7.47	6.73	4.92	5.21	5.35	6.00	5.78
G2 Male	7.34	6.05	5.65	5.92	5.82	5.63	6.32
G1 Female	7	4.83	6.25	6.75	4.86	5.33	6.75
G2 Female	6.53	6.65	6.50	6.00	4.69	5.71	5.31
G1 Rural	8.63	7	4.69	5.69	5	5.82	6
G2 Rural	7.76	5.64	6.21	6	5.28	5.56	5.5
G1 Urban	6.64	5.64	5.64	5.25	5.4	5.82	6.33
G2 Urban	6.62	7.12	5.68	6.13	5.79	5.89	6.63
G1 FGCS	6.67	6.63	5.79	5.33	4.91	4.6	5.78
G2 FGCS	7.95	6.70	6.33	6.04	5.36	6.1	5.59
G1 NFGCS	7.63	5.93	4.95	5.53	5.45	6.5	6.47
G2 NFGCS	6.72	6.18	5.68	6.09	5.68	5.52	6.44

in their rankings. The slight oscillations observed could be influenced by elements inherent to online learning, like personal comfort with the digital platform.

Looking deeper into gender-based differences, a notable pattern emerges. In the offline sessions (G1), male participants marked a significant dip in their ranking for Session 3. Conversely, the female participants recorded their lowest ranking during Session 5. Yet, both genders seem to rebound in the sessions that follow. In online sessions (G2), female participants consistently accorded higher rankings than their male counterparts, especially from Session 2 through Session 4. This suggests a potential preference or favourable reception of the online methodology among female participants.

When we look at which method seems more effective, some patterns emerge. If we think of effectiveness as having steady results, then the online method (G2) seems better, particularly for the female participants. They gave consistent

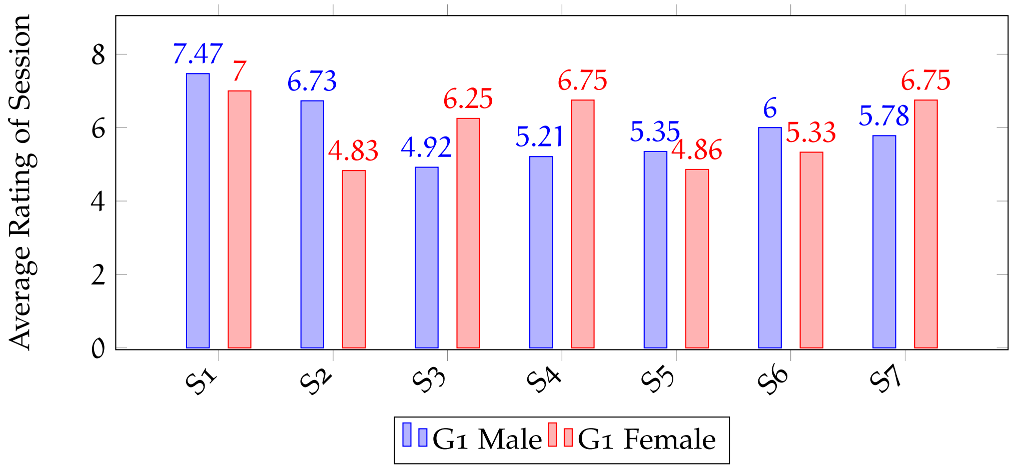

Figure 7.10: Average ranking across sessions for Online Group (G1) by Gender

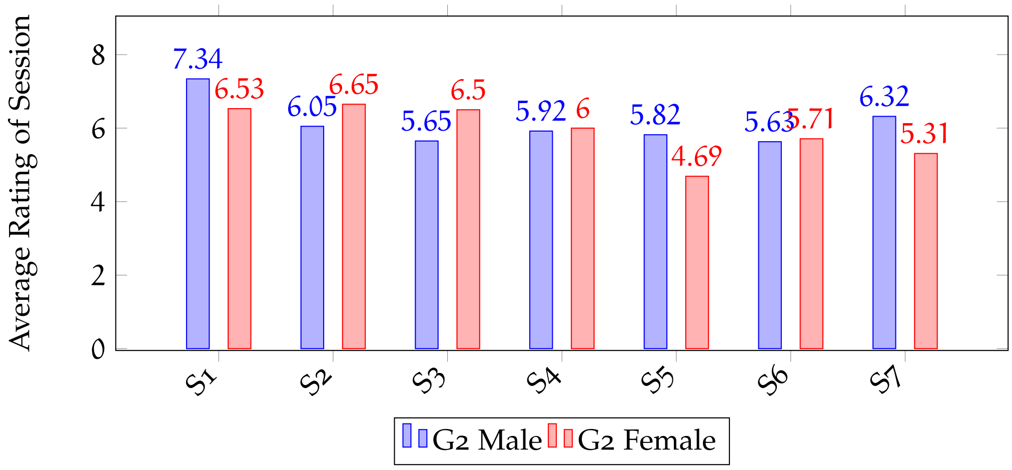

Figure 7.11: Average ranking across sessions for Offline Group (G2) by Gender

rankings across the sessions. However, with G1, there are more ups and downs in the rankings. These variations could give us important feedback about the comprehension of the topic in each session.

In summary, both the online and offline methodologies have their unique advantages. The online method provides consistency and might resonate more with certain demographics, as evidenced by the female participants in this study. However, the offline method, with its range in session rankings, offers invaluable insights for potential improvements. It is important to acknowledge that both scenarios have their strengths catering to the various needs of participants.

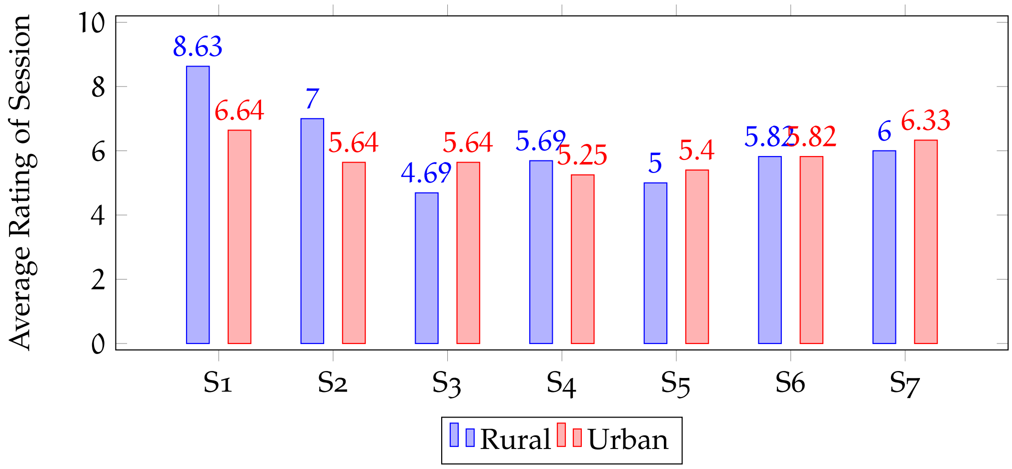

Figure 7.12: Average ranking across sessions for Group 1 (G1) by Environment

Environmental Upbringing Analysis

When we examine the data based on the Environmental upbringing of our participants, as seen in Figures 7.12 and 7.13, a selection of patterns emerge. In the first session for both G1 (8.63) and G2 (7.76) Rural groups showcased a much higher reaction than any other session. This was followed by a notable drop in Session 2 of G1 (7) and Session 2 of G2 (5.64) and could be attributed a possible initial comfort, followed by a struggle to adapt to the particular dynamics or content of the next session.

On the other hand, urban environments are characterised by their diversity and scale. Individuals from such backgrounds are likely accustomed to interacting with a wide variety of people, leading to a broader range of collaborative experiences. This might explain the relative consistency in scores across sessions for both G1 and G2 Urban groups. They might be better equipped to adapt to various collaborative scenarios due to their past exposure.

In summary, the backdrop against which participants have formed their collaborative habits, be it the intimacy of rural settings or the diversity of urban environments, appears to play a substantial role in their receptivity to a collaborative learning methodology.

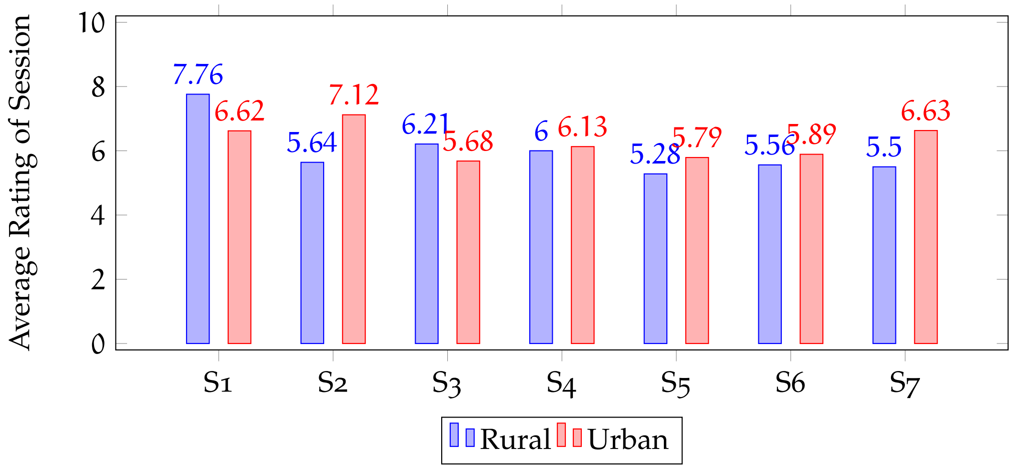

Figure 7.13: Average ranking across sessions for Group 2 (G2) by Environment

Parental Education Analysis

Referring to Figure 7.14 and Figure 7.15, we discern a marked contrast between the offline group (G1) and the online group (G2) for both First Generation College Students (FGCS) and Non-First Generation College Students (NFGCS). This shift may suggest that NFGCS gradually acclimate to the Collaborative Learning Sessions, extracting more value as they progress. Interestingly, post this shift, the ratings by FGCS also witnessed an upswing, possibly indicating a broader sentiment of comfort and engagement among all participants from Session 5 onwards.

In contrast, the online group (G2) displays a more uniform response. This consistency might allude to the idea that digital platforms can foster a more level playing field for collaborative learning. Nevertheless, a discernible drop in ratings around Session 4, akin to G1, hints at the session's increased challenge or perhaps a communal difficulty. However, the disparity between FGCS and NFGCS remains minimal, reinforcing the equitability of the online environment.

7.3.7 FIRST SEMESTER CONTINUOUS ASSESSMENT ANALYSIS

As discussed in Section 3.2, the problems we asked our participants to solve were included as part of the weekly laboratory for the CS161 module. Upon

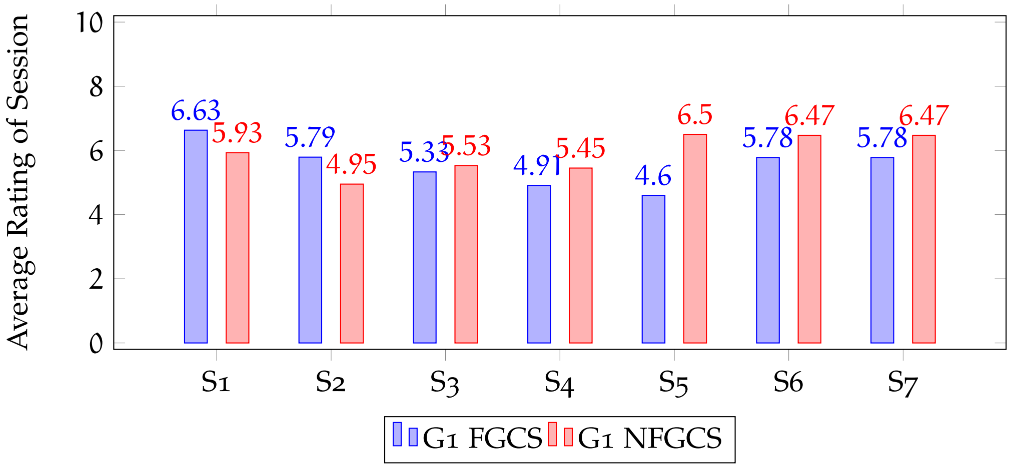

Figure 7.14: Average ranking across sessions for Group 2 (G2) by Parental Education

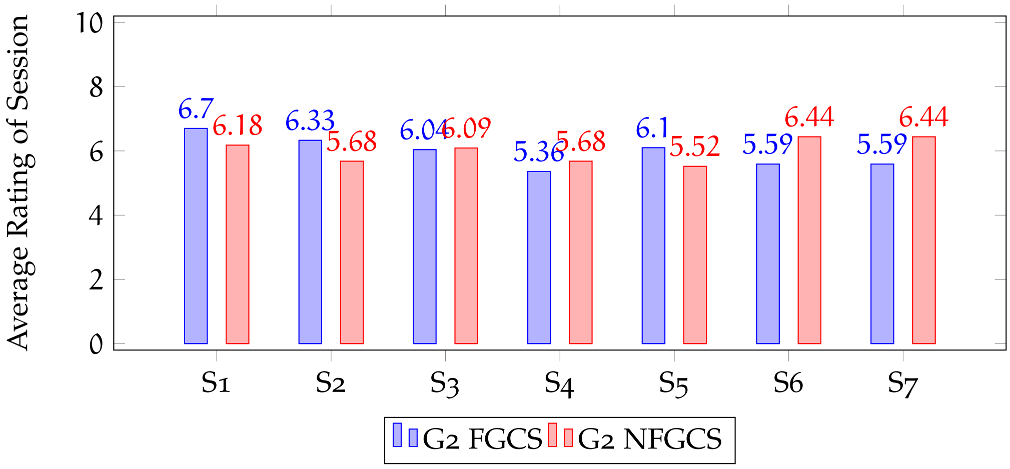

Figure 7.15: Average ranking across sessions for Group 2 (G2) by Parental Education

concluding the semester, we compiled this data for comparison to previous years. The data presented in Figure 7.16 shows the average score of students in the module, where 100% means they got the answer fully correct, and 0% means they did not receive a grade for the lab. A notable increase in the average grade was observed among students who participated in this study compared to their counterparts from the previous academic year. Specifically, the 2022 grades exceeded those of the 2021 cohort by an average of 8.1%. However, while this upward trend is certainly promising, it is essential to approach such data with caution. There exists an inherent threat to validity when comparing grades across different student batches. Nonetheless, it is affirming to witness an improvement in grades among those who engaged with the proposed methodology. It is worth noting that for this analysis, the lecture content remained the same year by year, along with the lecturer delivering the content and the content covered in the labs.

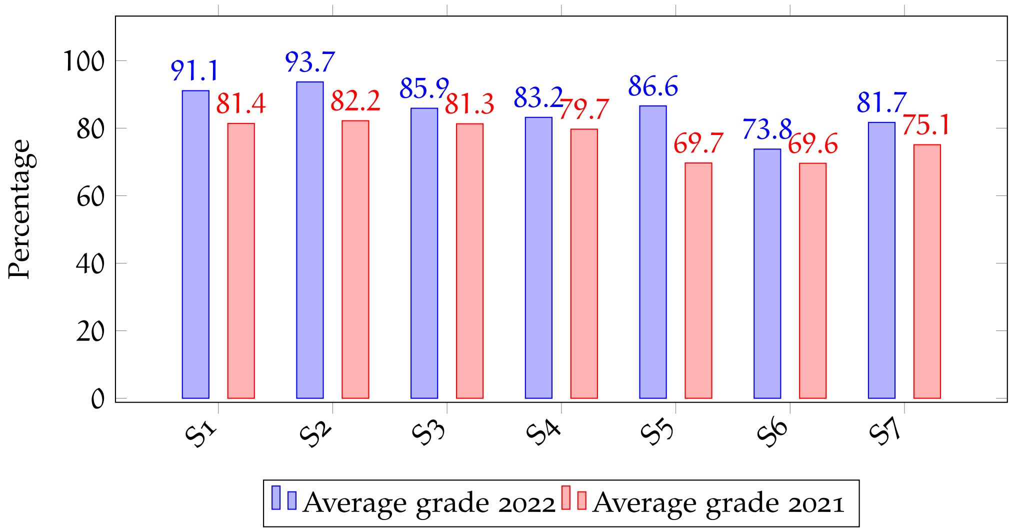

Figure 7.16: Comparison of Average Grades for 2022 and 2021

7.3.8 SECOND SEMESTER SESSION FEEDBACK

Within the second semester of our study, we focused on understanding the impact of our methodology in an online format. Our participants from our Online group (G2) were surveyed throughout 5 collaborative learning sessions in the second semester of the academic year. This was a factor in the decreased amount of participants surveyed as seen in Table 7.2. The findings of this survey are presented in Figures 7.17.

In the second semester of our study, our primary focus was on discerning the effectiveness of our methodology in a simulated online environment. This evaluation centered around participants from our online group, referred to as G2, and spanned over five collaborative learning sessions. It is noteworthy to mention that there was a discernible decrease in the number of respondents, a detailed breakdown of which can be found in Table 7.2. The results of this survey are portrayed in Section 7.3.8.1.

Survey Feedback

Upon a close examination of Figure 7.17, several key insights emerge. Firstly, the feedback for both personal and group work remained remarkably consistent throughout the sessions. This feedback stability suggests that the participants' perceptions remained relatively unaltered as they progressed through the sessions.

Furthermore, the feedback indicates a higher appreciation for personal work, particularly in Sessions 1, 3, and 5. This observation alludes to the possibility that during these specific sessions, individual work was perceived as more useful. In contrast, the fourth session saw a noticeable spike in the value participants derived from group activities. This implies that the content or perhaps the group work completed during this session was beneficial to gain a better understanding of the question.

The overarching takeaway from the data is that both personal and group learning methodologies received average feedback scores in the mid-5 to mid-6 range. This suggests that participants found merit in both learning strategies, with neither overshadowing the other. Going forward, it is important to acknowledge this and aim to improve the application to allow greater collaboration while also encouraging self-learning as an important aspect of this.

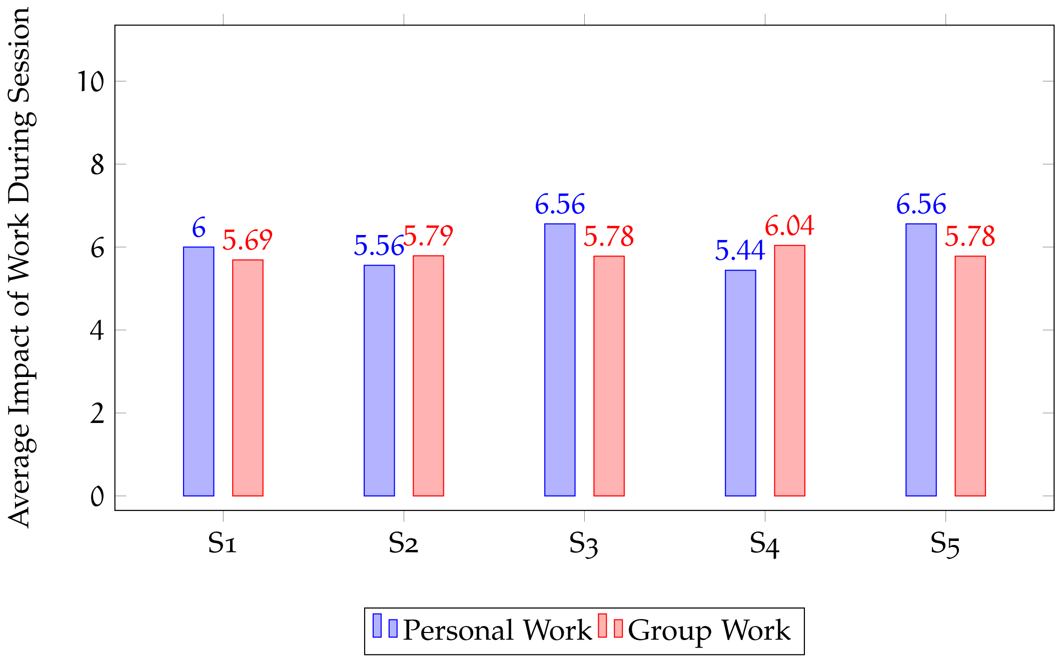

Figure 7.17: Comparison of Average G2 Personal Impact and Group Impact Over the Sessions.

Engagement Measurements

An examination of the engagement metrics sheds light on the usage pattern of our platform across the five sessions.

Starting with the messaging trends observed in Figure 7.18, it is evident that the first session saw the highest messaging activity, with a count of 433 messages. This could be attributed to participants acclimating themselves to the platform, introducing themselves, or even sorting out any initial clarifications. Following sessions stabilised in terms of messaging, with numbers hovering between 268 and 340 messages. The slight fluctuations might indicate variances in the session topic, collaborative task, or participant enthusiasm.

The trend for images sent, as depicted in Figure 7.19, provides a different narrative. Excluding the initial session, which saw a count of 2 images, the numbers indicate a consistently high engagement level in terms of visual content sharing. Session 2 marked a significant spike with 11 images compared to session 1 which only had 2, and this trend was sustained in subsequent

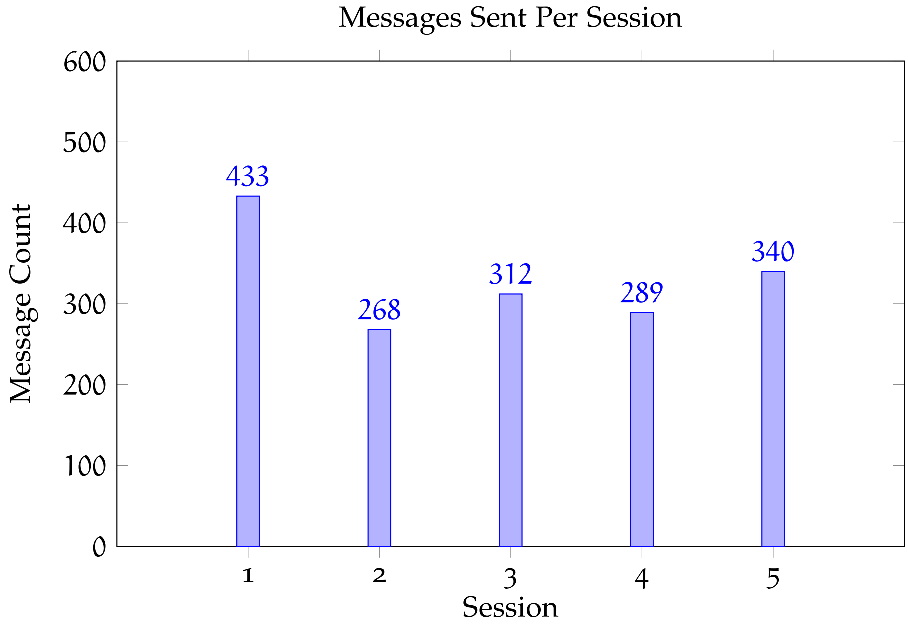

Figure 7.18: Number of messages per session.

sessions, highlighting the pivotal role of visual aids in online collaborative sessions.

The elevated counts in Sessions 4 and 5, specifically, might suggest an increased reliance on visual aids as the sessions progressed, perhaps due to the complexity of the topics discussed or a heightened comfort level with the platform.

These engagement metrics offer not only a quantitative measure of platform usage but also provide qualitative insights. The high message counts indicate active participation and discourse, while the consistent image sharing underscores the importance of visual aids in enhancing understanding and collaboration in a digital learning environment. While We did employ moderation strategies that limited the platforms use for inappropriate or spam, message and images. It is important to note that not all messages sent through the platform would be directly related to learning.

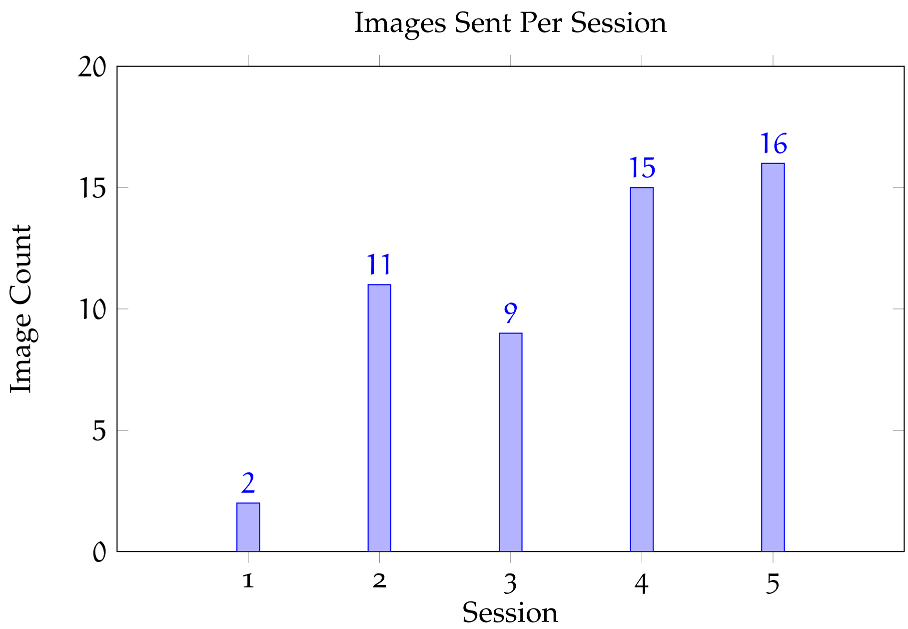

Figure 7.19: Number of images sent per session.

7.4 LESSONS LEARNED FROM THE YEAR-LONG STUDY

7.4.1 ENGAGEMENT

When working with our Online group, it was essential to encourage students to stay engaged with the activity on their phones rather than switch to different applications. In future studies, it would be ideal to trial the methodology with a fully online course or for online activities as part of a blended learning course. This could help prevent distractions that can discourage students from staying engaged with the task.

7.4.2 APPLICATION CONSTRAINTS

To address constraints that affected some of our participants namely, international students, those with older mobile phones, or those using iOS beta apps, we were compelled to pivot, embracing both mobile and web applications to foster inclusivity.

Upon launching our application on Android and iOS platforms, distinct challenges associated with each became apparent. While Android was relatively lenient regarding the content permitted on their store, geographical origins posed significant hurdles. Although our application fulfilled the criteria for being hosted on the Google Play Store in countries like Ireland and England, we encountered challenges rooted in data privacy regulations in nations such as Spain, China, and Germany. Consequently, international students, even if currently residing in Ireland, found themselves unable to install the app.

In contrast, the Apple ecosystem presented a unique set of challenges. The prerequisites for listing on their official App Store were financially demanding and stringently outlined. As well as this, opting for their beta App Store presented connectivity issues with our platform.

Due to these challenges, a segment of our student population was equipped with mobile phones incompatible with the application's requirements. Given these multifaceted challenges, we endeavoured to ensure that our web application had the same functionalities and capabilities as its mobile counterpart.

7.5 CONCLUSIONS

This chapter explored the implications of an online learning environment for collaborative learning. The demographic analysis of both the Offline group (G1) and Online group (G2) brought forth insights into the diverse backgrounds of participants, covering aspects like gender, environmental background, and parental education. These demographics play a pivotal role in understanding how different groups perceive and benefit from collaborative learning environments.

The results from our first semester's continuous assessment are promising. We observed an 8.1% improvement in average grades in 2022 compared to 2021 after introducing our new learning approach. It is worth noting, however, that while these results are encouraging, differences between student batches can play a role. However, with the lecture content and the educator remaining consistent over the years, it suggests our methods had a positive effect.

The feedback from G2, collected after their online sessions, offered profound insights into the overall effectiveness of the adopted methodology. While both individual and group activities were deemed beneficial, there were instances where individual work outperformed group activities, suggesting that learners occasionally found deeper understanding in personal work. The dynamics between individual introspection and collaborative effort remain a focal point of our study.

The engagement statistics acted as a measure of participant involvement, with the volume of messages and shared images acting as indicators of active participation and the reliance on visual aids, respectively. Observing these metrics over our five sessions outlined the evolution of engagement in our platform from initial apprehensions and icebreakers to participants getting more involved and utilising the application features to the fullest.

This chapter provides a deep look into the effect of a collaborative learning strategy on both an offline and simulated online cohort. Overall, our combined analysis of each of the above points us in a positive direction regarding the efficacy of our methodology in a University setting.

Part IV

CONCLUSIONS

8 DISCUSSION AND FUTURE WORK

8.1 CONCLUSIONS

8.1.1 METHODOLOGY CREATION

The first goal of this research project was to design and test a pedagogical methodology that could introduce collaborative learning within pre-existing learning activities. This methodology should be implemented in tandem with the application developed alongside the methodology and should support and evaluate students learning by increasing the amount of active participation in a task. This methodology has been utilised by over 1000 students in 3 university modules. The feedback by supporting staff members and students, who have taken part in or helped facilitate the methodology has been incredibly positive. The methodology is simple by design and effective in introducing active learning even without the use of the application. A detailed breakdown of the methodology for students and supporting staff can be found in Appendix **??**.

8.1.2 APPLICATION DEVELOPMENT

For the second goal, we aimed to design and construct a functional online platform to support collaborative learning. We are confident that we have met this aim. Our application underwent testing across various versions in our subsequent studies, and the feedback garnered from students was largely favourable. Students effectively collaborated using our platform, with many expressing a preference for this mode of interaction over the traditional offline CLS. In future work as described in Section 8.2.1 we hope to improve upon the features that we offer to continue providing an effective collaborative tool.

8.1.3 pilot study

As highlighted in Chapter 5, the pilot study aimed to establish a base for our collaborative methodology principles. The goal was to discern if our group study approach could boost subject interest and engagement.

Over four sessions, varying participation and feedback were evident. These patterns suggest topic complexity and presentation style might influence engagement and interest. Demographically, male respondents rated sessions higher than females. Feedback differences between urban and rural participants and between first-generation college students and others underscore the nuanced influences on collaborative learning.

Session timing was crucial for engagement. Ample personal study time led to enhanced collaboration, hinting at a balance between solo and group study. A challenge was the dip in survey participation, emphasising the need for robust feedback methods.

Despite largely positive results, the study emphasises tailoring collaborative learning to diverse student backgrounds and needs. As our CLS method evolves for hybrid and online formats, refining the approach to serve varied students and more conclusively address the research question is paramount.

8.1.4 cs620c study

Chapter 6 thoroughly examined the CS620C study, unearthing key insights and lessons that furthered our research aims. Set within the rigorous three-week module of CS620C, the study presented unique challenges and opportunities. The module attracted participants with diverse academic and professional backgrounds, enriching the collaborative learning sessions with varied perspectives.

An oversight in data anonymisation curtailed our quantitative analysis, emphasizing the need for meticulous data management. Nevertheless, the qualitative feedback was instrumental, steering enhancements to our collaborative learning tool. The feedback demonstrated the benefits of collaborative learning, illustrating how group interactions enriched comprehension and fostered subject interest.

While hurdles were encountered, they highlighted areas for advancement. Feedback from the initial web application emphasized its merits and shortcomings. This feedback, aligned with our developmental plans, validated our intended direction.

8.1.5 year long study

This chapter looks into the nuances of an online learning setting for collaborative education. Through demographic analysis of both Offline (G1) and Online (G2) groups, we gained insight into participants' varied backgrounds, crucial for understanding perceptions of collaborative learning. Our results show an encouraging 8.1% rise in grades in 2022 versus 2021, implying the effectiveness of our introduced approach, especially given consistent lecture content and educator.

Feedback from G2 highlighted the overall effectiveness of our methodology, noting the value of both group and individual activities. Furthermore, engagement metrics, such as message volume and shared images, depicted the growing participation from initial hesitations to full platform immersion.

8.1.6 contribution to the state of the art

The peer-reviewed publications that arose as a result of the research contained in this thesis are as follows:

S. O'Neill and A. Mooney. "Introducing a collaborative learning strategy in a hybrid and traditional laboratory for undergraduate computer science students." In: *9th International Conference on Higher Education Advances (HEAd'23)* (2023)
The presentation of data from our studies demonstrates how our methodology is effective in increasing a student's understanding of the work

being assessed and contributes to an increase in students' assessment grades.

S. O'Neill and A. Mooney. "Developing a Collaborative Learning Application to Support Effective Student Collaboration in Hybrid Learning Environments". In: *EDULEARN23 Proceedings, pp. 4931-4936.* (2023)
This publication details the development process of creating our application for supporting online collaborative learning. This application will facilitate and encourage collaboration amongst students.

S. O'Neill and A. Mooney. "Investigating the Impact of Collaborative Learning on Undergraduate Computer Science Students". In: *EDULEARN23 Proceedings, pp. 4986-4992.* (2023)
The effect of online and collaborative learning on different demographics was a key element we found through our literature review to be unexplored. In this publication we investigate how the background of a student can effect their learning experience in a collaborative environment.

8.2 FUTURE WORK

8.2.1 CONTINUE MOBILE AND WEB APPLICATION DEVELOPMENT

The various iterations of our application used in this research laid a solid groundwork, showcasing the potential of tools like Staidr in academics. We are confident that such a tool holds immense promise for learners across all educational levels. Our aim is to build upon the essential functionalities detailed in Table 4.1, integrating desired features like video and voice chat, along with real-time document collaboration. By enhancing such functionalities, the application will vastly improve the study experience, fostering richer collaboration beyond the classroom. To maximise the tool's reach and impact, ensuring its accessibility across diverse platforms is paramount. We envision Staidr becoming a vital companion app throughout a student's academic journey, compatible with every major mobile and desktop platform. Furthermore, as a course progresses, giving students access to peer-sourced notes can prove invaluable. We aim to enhance our note-sharing feature, streamlining the verification and editing processes of shared materials within the platform. Lastly, we recognise the need to bolster our administrative features. By simplifying the moderation process and group creation functionalities, we hope to empower educators and administrative personnel to seamlessly integrate collaborative learning strategies into their curriculum.

8.2.2 FURTHER STUDIES

The next step for our research is to extend the trials to various departments within the university. One limitation we acknowledged during this project was the narrow focus on computer science-centric modules. By investigating the applicability and impact of our methodology in diverse academic fields, we can gain a more comprehensive understanding of its efficacy. This broader approach will offer insights into varied learning styles and potentially unveil additional areas where our tool can make a significant difference.

APPENDIX A

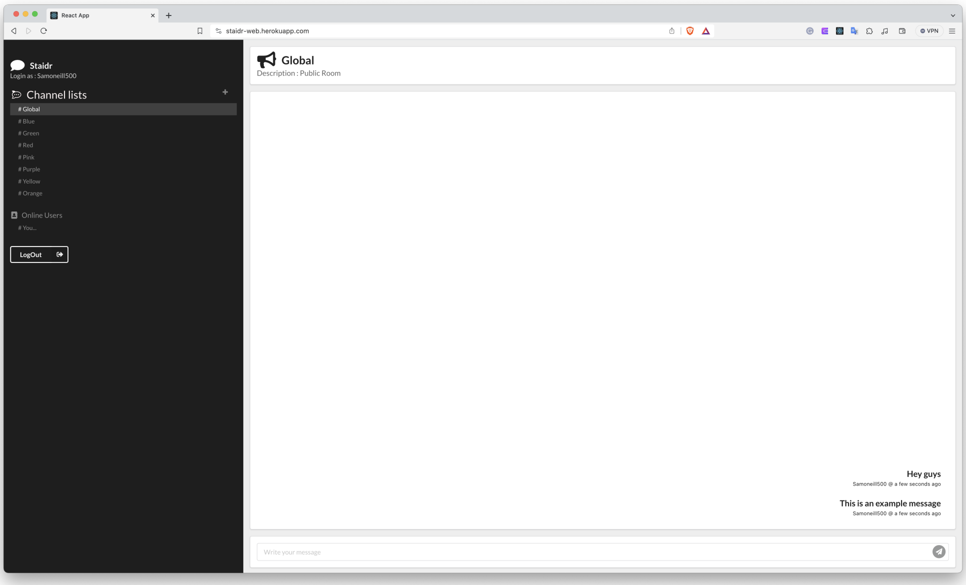

Figure A.1: Web Application Version 1

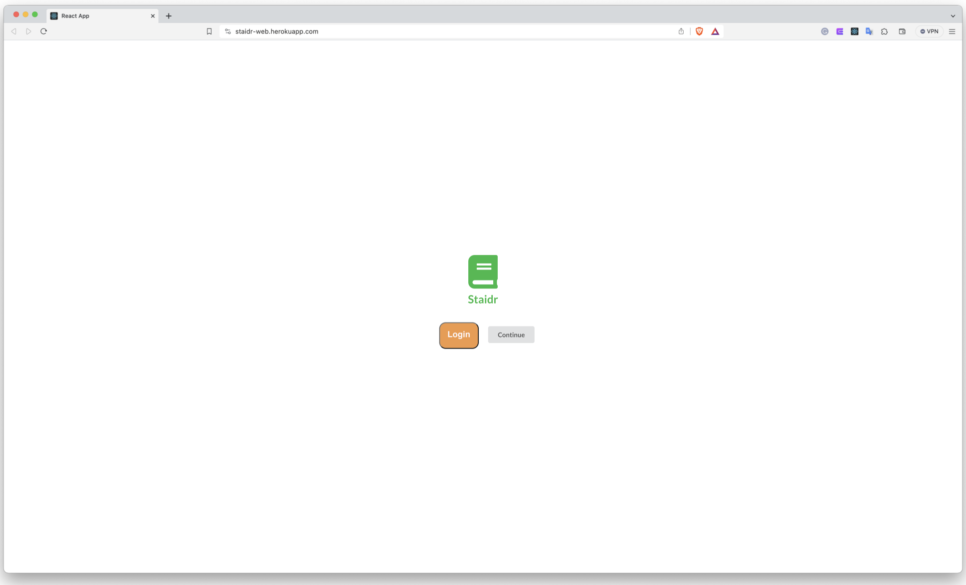

Figure A.2: Web Application Version 2 Login Page

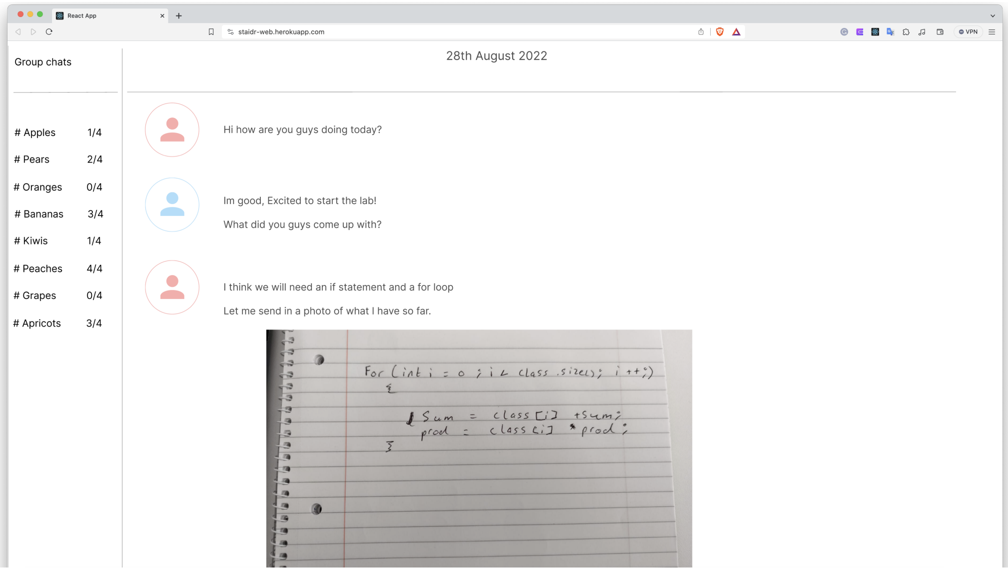

Figure A.3: Web Application Version 2 Group Page

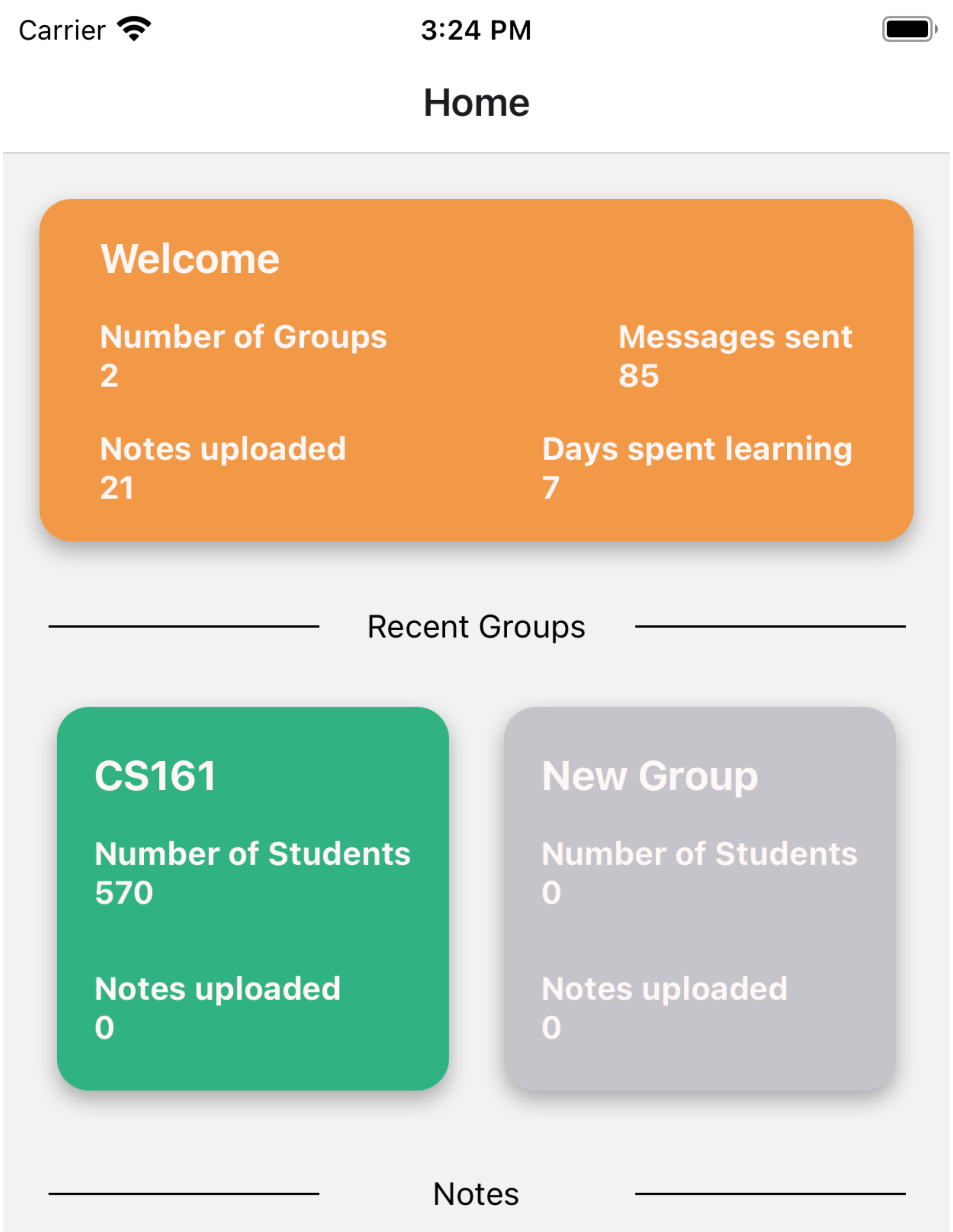

Figure A.4: Mobile Application Home Page

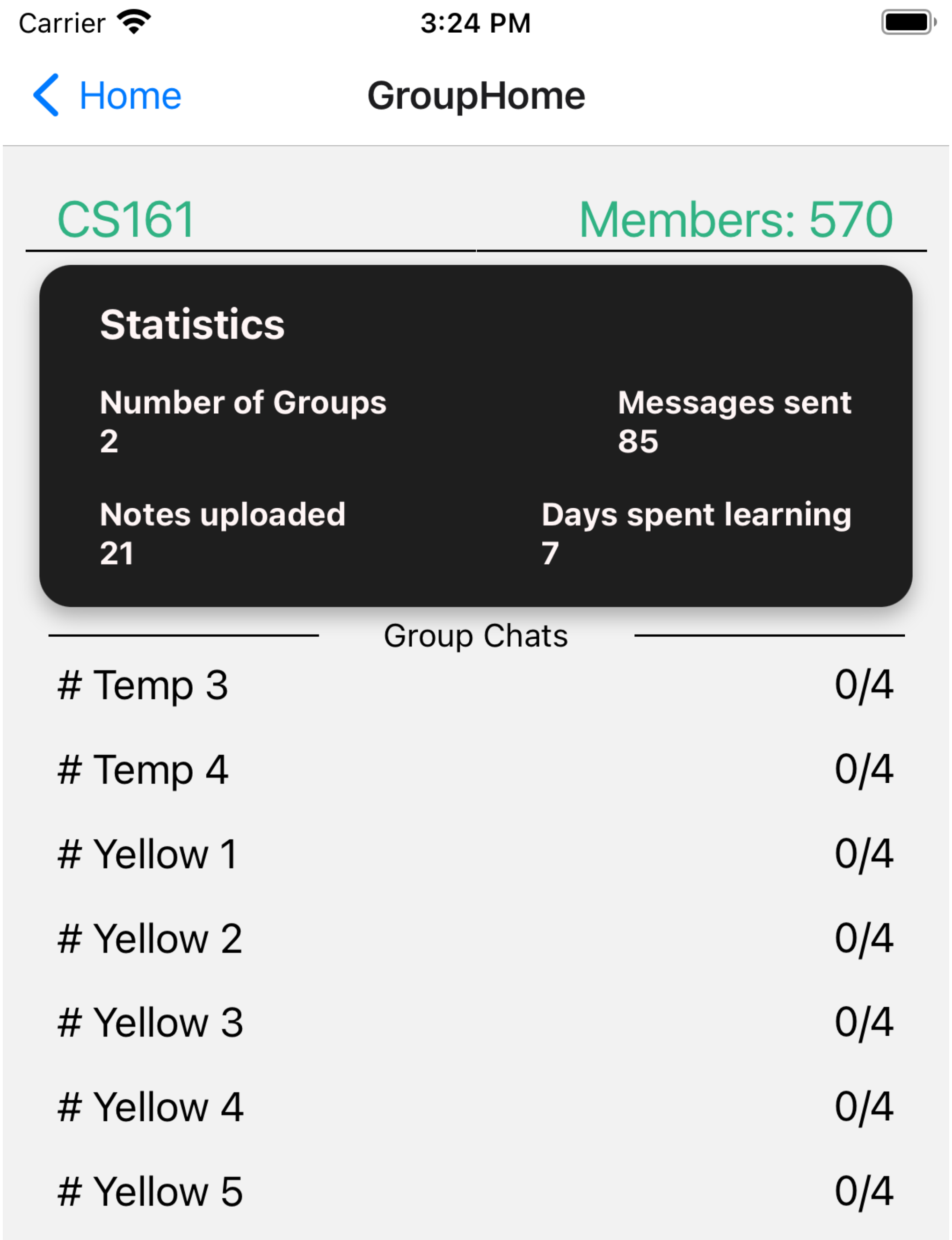

Figure A.5: Mobile Application Module Page

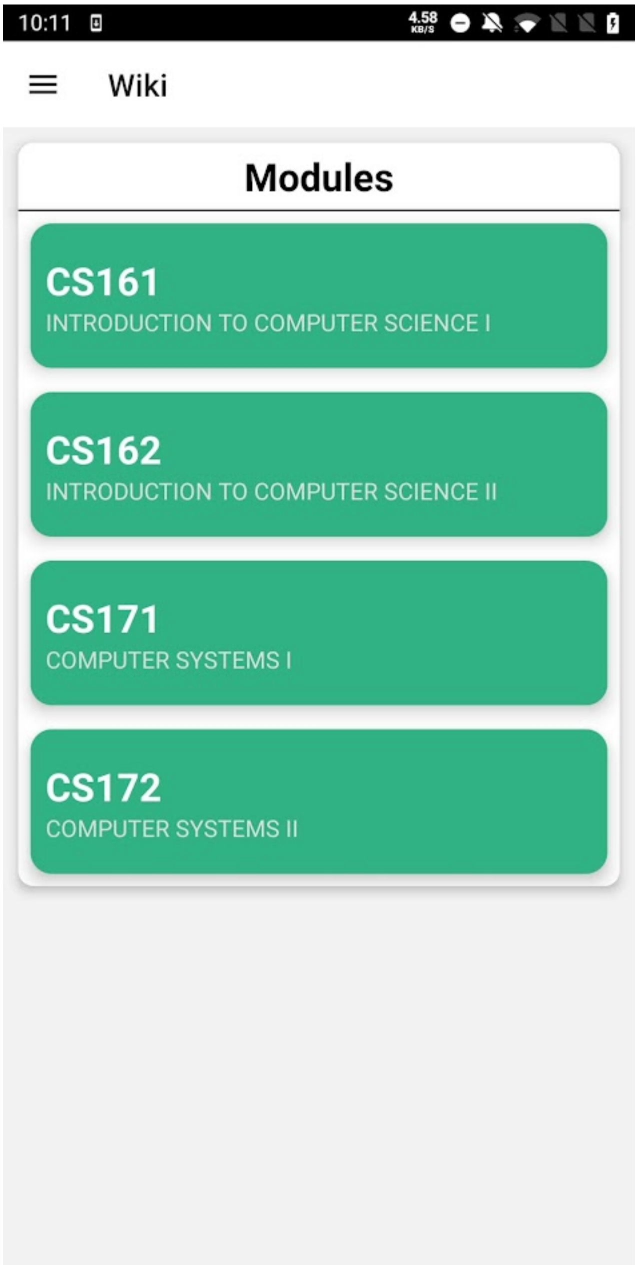

Figure A.6: Note Sharing Module Selection

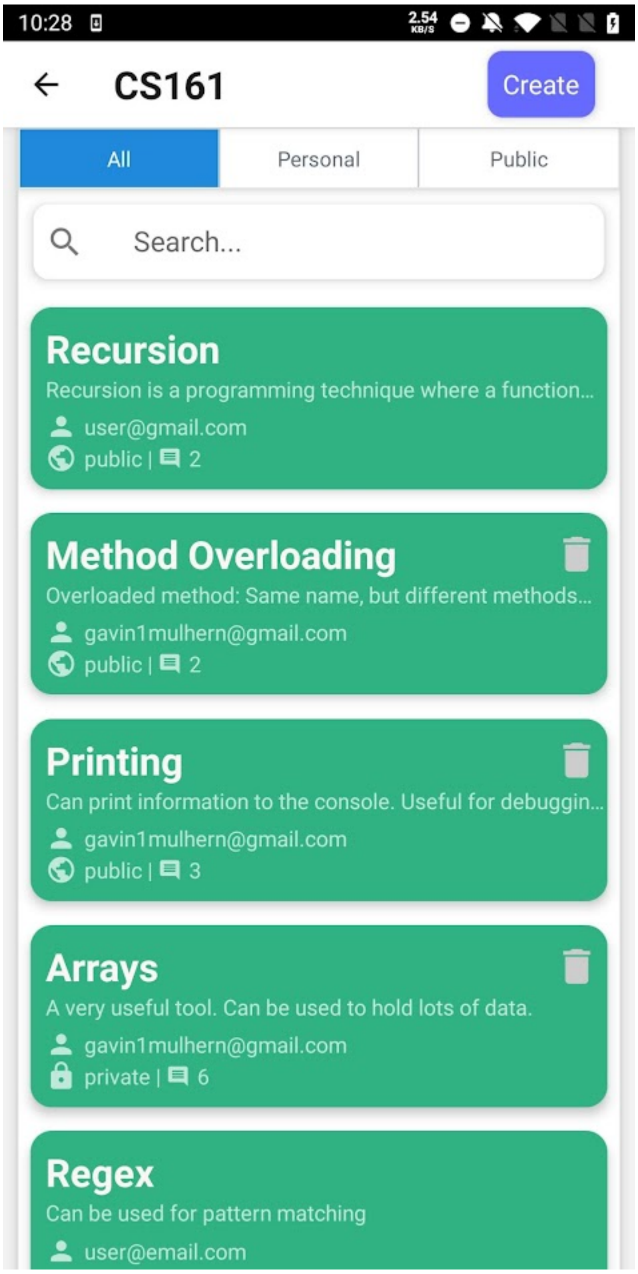

Figure A.7: Note Sharing per Module

APPENDIX B

```
const groupSchema = new Schema(
  {
    Name: {
      type: String,
    },
    Rooms: {
      type: Array,
      items: {
        type: Object,
        properties: {
          Active_users: {
            type: Int32,
          },
          Room_name: {
            type: String,
          },
        },
      },
    },
    TotalMessagesSent: {
      type: Long,
    },
    Users: {
      type: Array,
      items: {
        type: Object,
        properties: {
          Joined_flag: {
            type: Boolean,
          },
          User_id: {
            bsonType: 'objectId',
          },
            User_name:{
              type: String
            },
        },
      },
    },
  },
  {type: Int32, required: true},
);
module.exports = mongoose.model( name: 'groups', groupSchema);
```

Figure B.1: MongoDB Group Schema Example

```
const userSchema = new Schema(
  {
    email: {
      type: String,
    },
      Groups: {
          type: Array,
          items: {
              type: Object,
              properties: {
                  Group_name: {
                      Type: String,
                  },
                  Rooms: {
                      type: Array,
                      items: {
                          type: Object,
                          properties: {
                              Active_users: {
                                  type: Int32,
                              },
                              Room_name: {
                                  type: String,
                              },
                          },
                      },
                  },
              },
          },
      },
  },
    {type: Int32, required: true},
);
module.exports = mongoose.model( name: 'users', userSchema);
```

Figure B.2: MongoDB User Schema Example

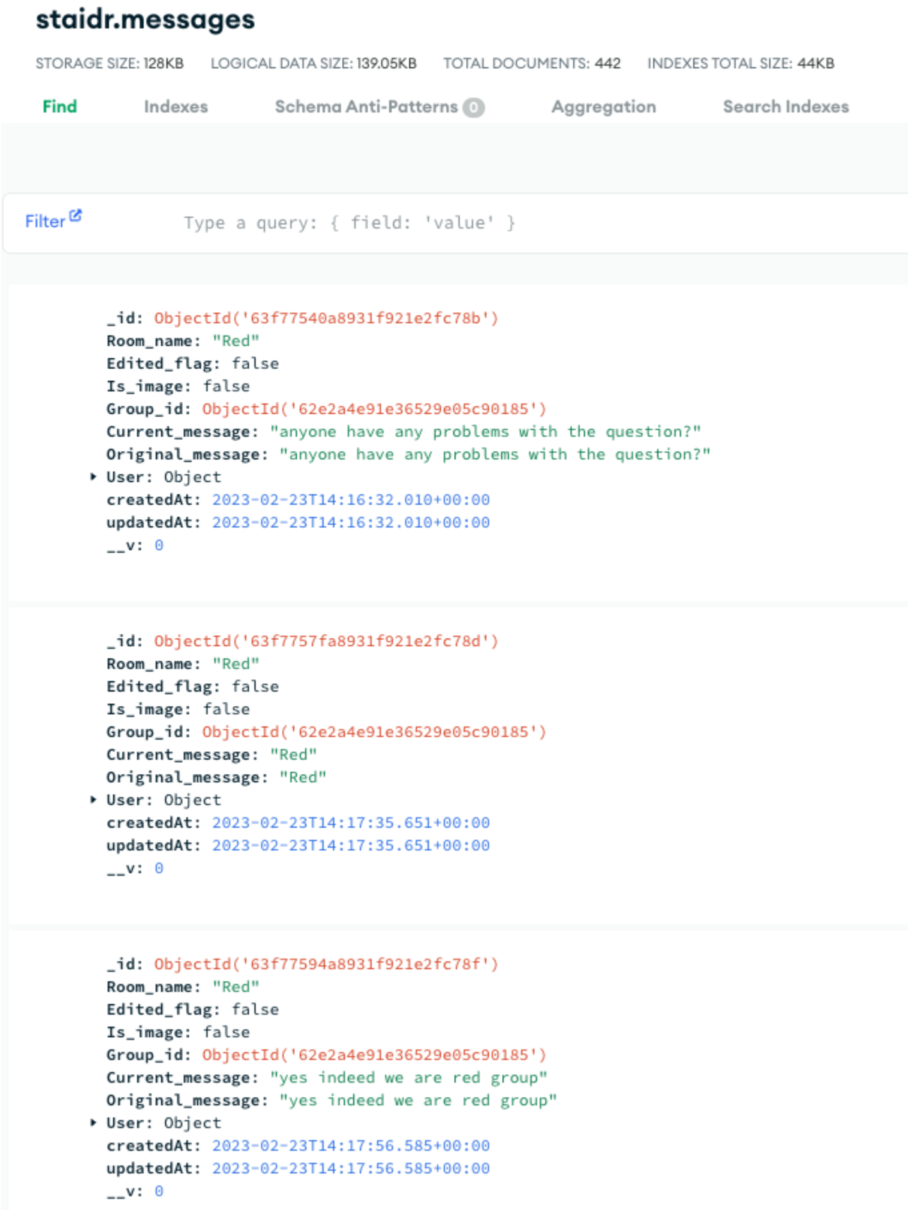

Figure B.3: MongoDB Atlas Message Example

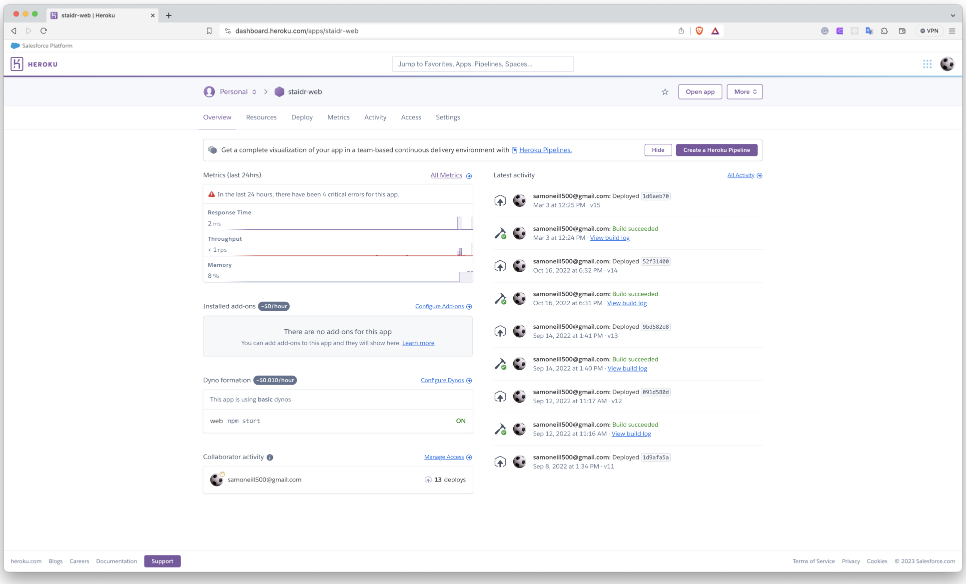

Figure B.4: Heroku Deployment

APPENDIX C

Student Information Sheet relating to the completion of the online survey

Research Project:	Facilitating online study groups through a mobile and desktop application.
Aim:	Analyse, develop and implement a methodology and platform for creating hybrid/learning study groups.
Researcher:	Dr Aidan Mooney, Department of Computer Science, Maynooth University, Maynooth, Co. Kildare. Mr Sam O'Neill, Department of Computer Science, Maynooth University, Maynooth, Co. Kildare.
Contact details:	Aidan Mooney, aidan.mooney@nuim.ie Sam O'Neill, sam.oneill@mu.ie

The Purpose:

As part of our research, we are looking into collaborative learning and how it can be facilitated in both an in person and online environment. In this project we will investigate the benefits of using collaborative learning to approach a problem and to determine if there is an increase in a student's understanding when it comes to forming a solution.

The Tasks:

We have created an online survey, which we would appreciate if you could fill out. All data will be anonymised, and no personal information will be stored. There is no requirement on you to complete this survey, but we would appreciate your input.

Anonymity and security of data:

Your permission will allow us to include your data in potential publications. As stated above no personal information will ever be shared with anybody other than the researchers, we will just be using the feedback to compare different demographics (age/gender etc.).

Confidentiality Commitment:

We assure you that the information you share with us will remain completely confidential and that no data containing information that discloses your identity will be stored, released or published. However, it must be recognized that, in some circumstances, confidentiality of research data and records may be overridden by courts in the event of litigation or in the course of investigation by lawful authority. In such circumstances the University will take all reasonable steps within law to ensure that confidentiality is maintained to the greatest possible extent.

Questions:

If you have any further questions, please contact the researchers using the above contact details.

APPENDIX D

Initial Survey

* Required

1. Please confirm that if you consent to the following statements *

I agree to participate in the Research study titled
"Facilitating online study groups through a mobile and desktop application", being undertaken by Sam O'Neill and Dr Aidan Mooney.

I am participating voluntarily.

I have been provided with information and I understand:
- About the purpose and nature of the study.
- That I can withdraw from the study, without repercussions, at any time
- How my data will be managed
- The limits of confidentiality in this study
- The ways in which my data, in an anonymous format, may be used
- How I can ask questions about the study

I agree for my data to be used as outlined in the information sheet

◯ I consent

◯ I do not consent

2. Please enter your age *

The value must be a number

3. Have you previously compeleted a third level course? *

- ◯ Yes
- ◯ No

4. What was the area of your previous course? e.g. economics, maths, etc...

5. What is your current college course? *

- Ba Finance
- Ba International Finance & Economics
- Ba Media Studies
- Bachelor Of Arts
- Bachelor Of Data Science
- Bachelor Of Science
- Bsc Computer Sci & Software Engineering
- Bsc In Quantitative Finance
- Bsc In Robotics And Intelligent Devices
- Bsc Mathematics With Education
- Bsc Maths & Computer Sci With Education
- Bsc Multimedia, Mobile & Web Development
- Bsc Pharmaceutical& Biomedical Chemistry
- Bsc Physics With Astrophysics
- Other

6. What is your gender? *

- Woman
- Man
- Non-binary
- Prefer not to say

7. Are you a first generation college student?

(A student whose parent(s) did not complete a college or university degree.) *

- Yes
- No

8. Did you sit the leaving certificate *

- Yes
- No

9. What points did you receive in the leaving cert? (If unsure, add an approximate value)

The value must be a number

10. Are you form a rural or an urban background? *

- ◯ Rural
- ◯ Urban

11. Have you ever taken part in group study before? *

- ◯ Yes
- ◯ No

12. How helpful did you find this group study?

1 being not helpful and 5 being very helpful

1	2	3	4	5

13. Would you be interested in participating in a computer science focused study group? *

- ◯ Yes
- ◯ No

APPENDIX E

Follow up survey

* Required

1. Please confirm that if you consent to the following statements *

I agree to participate in the Research study titled
"Facilitating online study groups through a mobile and desktop application", being undertaken by Sam O'Neill and Dr Aidan Mooney.

I am participating voluntarily.

I have been provided with information and I understand:
- About the purpose and nature of the study.
- That I can withdraw from the study, without repercussions, at any time
- How my data will be managed
- The limits of confidentiality in this study
- The ways in which my data, in an anonymous format, may be used
- How I can ask questions about the study

I agree for my data to be used as outlined in the information sheet

- ○ I consent
- ○ I do not consent

2. Did you complete an offline session or an online session this week? *

- ○ Offline
- ○ Online

3. How helpful did you find the 30 minute session? *

1 being not helpful at all and 10 being Extremely helpful

1	2	3	4	5	6	7	8	9	10

4. Do you have a preference between working on your own or within a group? *

- ○ I prefer working on my own
- ○ I prefer working within a group
- ○ I have no preference

5. Was the individual work helpful for gaining a better understand the question? *

1 being not helpful at all and 10 being Extremely helpful

1	2	3	4	5	6	7	8	9	10

6. Was the group work helpful for gaining a better understand the question? *

1 being not helpful at all and 10 being Extremely helpful

1	2	3	4	5	6	7	8	9	10

F

APPENDIX E

Student's instruction set

This week, you'll be participating in a collaborative work session as part of your lab. You will complete this session in the first 30 minutes of your lab. It is important to note that this session will **NOT** affect your CA assessment.

A summarised guide is available below.

What can be expected:

- Mule will open the hidden question at the start of your lab as usual.
- This session will ask you to think through the hidden question on paper independently for 5 minutes.
- Thinking about the following may help you get started
  - What is the question asking you to do?
  - What variables will you need to complete the question?
  - Will you need conditionals or loops?
  - Can the question be broken in to smaller pieces?
- For approximately 25 minutes, you will then work collaboratively with a small group of classmates to produce an algorithm for the question.
- This algorithm will be shown to demonstrators in the last 5 minutes of the session.
- You must show your individual work and teamwork to a demonstrator at the end.
- There will also be two optional surveys for you to participate in, which will help one of your demonstrator's research project.

What is an algorithm?

An algorithm is a detailed sequence of steps required to solve a problem.

Example of algorithms:

<u>How to cook an egg</u>

1. Fetch a Saucepan
2. Half fill with water
3. Place saucepan on cooker
4. Apply heat to boil water
5. Place egg in boiling water
6. Keep boiling for 3 minutes
7. Remove egg

Adding two numbers entered by a user

- Declare variables num1, num2 and res
- Read in values num1 and num2
- Add num1 and num2 and assign result to res
    - sum = num1+num2
- Print res to screen

Binary search through a sorted array

Method Binary Search

- Declare Ar as the sorted array, N as the size of the array, num1 as the value to be searched
- Set the low equal to 1 and the high equal to N
    - while num1 is not found
        - Set the middle equal to low + (high - low) / 2
        - If Ar [middle] < num1
            - Set low equal to middle + 1
        - if Ar [middle] > num1
            - Set high equal to middle + 1
        - if Ar [middle] equals num1
            - Exit "X is found at location middle"
    - end while
- end Method

Summarised guide to students

Step 1 Each student should individually read the specification for the hidden question and take notes on this. Each student should rewrite some aspects of the spec in their own words and highlight where they need clarification (5 minutes)

Step 2 Students should discuss and use pen-and-paper to outline the problem and describe their approach to writing the algorithm. (see information above on algorithm design including the data types and logic in an algorithm). The outcome of this will be 1 page of written text including diagrams describing the approach to be taken to solve the assignment. (10 minutes)

Step 3 A group representative should show their demonstrator their outline to solving the problem and ask her/him for clarifications on any issues that the group could not understand. (10 minutes)

Step 4 After the discussion with the demonstrator, the group should edit their algorithm based on the feedback they received from the demonstrator. (5 minutes)

Step 5 The demonstrator signs off on the solution and the students continue working independently. Consultation is still allowed between group members beyond this 30-minute exercise.

Demonstrator instruction set

For this week's labs, the students will participate in a collaborative learning session like paired programming for the first thirty minutes. It is important to note that this session will **NOT** affect their CA assessment.
This work aims to help prepare them for their end of semester examinations, improve essential soft skills that are used in industry, and help them better form their solution to the hidden question.

What can be expected:

- We will be asking them to take ten minutes to independently think through the hidden question for this week on bubble sorting and begin to form an algorithm on paper.
- You can use this time to make sure everyone on your row understands the purpose of this session.
- The students will then move into groups of 3 or 4 depending on availability within their rows, and they will spend twenty minutes working together to produce a complete algorithm.
- During this section, you can walk between groups asking probing questions such as
    - Does everyone understand the current algorithm?
    - What variables do you expect to use in this question?
    - How did you implement this in your individual work?
- It is important to make sure every student gets a chance to speak. If you think one student is dominating the conversation, try to get everyone involved by asking other students how they would approach this question.
- In the last five minutes of the session, you can go through your row and check that each student has produced some individual work paper and group work.
    - Place one tick next to their name if they showed some individual work and two if they have produced something as a group.

Examples of complete Algorithms:

<u>How to cook an egg</u>

1. Fetch a Saucepan
2. Half fill with water
3. Place saucepan on cooker
4. Apply heat to boil water
5. Place egg in boiling water
6. Keep boiling for 3 minutes
7. Remove egg

<u>Adding two numbers entered by a user</u>

- Declare variables num1, num2 and res
- Read in values num1 and num2
- Add num1 and num2 and assign result to res
    - sum = num1+num2
- Print res to screen

<u>Binary search through a sorted array</u>

Method Binary Search

- Declare Ar as the sorted array, N as the size of the array, num1 as the value to be searched
    - Set the low equal to 1 and the high equal to N
- while num1 is not found
        - Set the middle equal to low + (high - low) / 2
- If Ar [middle] < num1
        - Set low equal to middle + 1
- if Ar [middle] > num1
        - Set high equal to middle + 1
- if Ar [middle] equals num1
    - Exit "X is found at location middle"
    - end while
- end Method

Summarised guide to students and demonstrators

Step 1 Each student should individually read the specification for the assignment and take notes on this. Each student should rewrite some aspects of the spec in their own words and highlight where they need clarification (5 minutes)

Step 2 Students should discuss and use pen-and-paper to outline the problem and describe their approach to writing the algorithm. (see information above on algorithm design including the data types and logic in an algorithm). The outcome of this will be 1 page of written text including diagrams describing the approach to be taken to solve the assignment. (10 minutes)

Step 3 A group representative should show their demonstrator their outline to solving the problem and ask her/him for clarifications on any issues that the group could not understand. (10 minutes)

Step 4 After the discussion with the demonstrator, the group should edit their algorithm based on the feedback they received from the demonstrator. (5 minutes)

Step 5 The demonstrator signs off on the solution and the students continue working independently. Consultation is still allowed between group members beyond this 30-minute exercise

Note: The demonstrator should be prepared for this task by studying the hidden question, solving the problem (coding it) and be able to explain his/her decisions to a group of students. The group does not have to follow the demonstrator's solution, but they must be able to explain to the demonstrator their reasons if they choose a different approach.

BIBLIOGRAPHY

[1] L. Alem and S. Kravis. "Design and Evaluation of an Online Learning Community: A Case Study at CSIRO". In: *ACM SIGGROUP Bulletin* 25 (2005).

[2] D. R. Arendale and A. R. Hane. "Holistic growth of college peer study group participants: Prompting academic and personal development". In: *Research and Teaching in Developmental Education* (2014).

[3] T. Babić and L. Miličević M Kolar. "Individual, Cooperative and Collaborative Learning and Students' Perceptions of Their Impact on Their Own Study Performance." In: *44th International Convention on Information, Communication and Electronic Technology (MIPRO)* (2021).

[4] Blaschke L. M. Brindley J. E. and C. Walti. "Creating effective collaborative learning groups in an online environment". In: *International Review of Research in Open and Distributed Learning, 10(3).* (2009).

[5] K. A. Bruffee. *Collaborative Learning: Higher Education, Interdependence, and TheAuthority of Knowledge.* Johns Hopkins University Press, 1999.

[6] P. A. Burrowes. "A student-centered approach to teaching general biology that really works: Lord's constructivist model put to a test." In: *The American Biology Teacher, 65(7), 491-502.* (2003).

[7] Y.H. Chen and P.J. Chen. "MOOC Study Group: Facilitation Strategies, Influential Factors, and Student Perceived Gains". In: *Computers Education 86 (2015): 55-70.* (2015).

[8] R. Chiong and J. Jovanovic. "Collaborative learning in online study groups: An evolutionary game theory perspective." In: *Journal of Information Technology Education: Research, 11(1), 81-101.* (2012).

[9] Davis D.L. Buckley I.A. Clarke P.J. and G. Potvin. "Combining learning and engagement strategies in a software testing learning environment". In: *ACM Transactions on Computing Education (TOCE), 22(2), pp.1-25.* (2021).

[10] N. Culligan. "Two Roads Diverge:Mapping the Path of Learning for Novice Programmers Through Large Scale Interaction Data and Neural Network Classifiers". PhD thesis. National University of Ireland, Maynooth (Ireland), 2021.

[11] N. Culligan and K. Casey. "Building an Authentic Novice Programming Lab Environment". In: 2018.

[12] Department of Education and the Department of Further and Higher Education, *Education Indicators for Ireland 2022*. Tech. rep. Department of Education, the Department of Further, and Higher Education, 2023.

[13] U. Desai, V. Ramasamy, and J. D. Kiper. "A study on student performance evaluation using discussion board networks." In: *Proceedings of the 51st acm technical symposium on computer science education* (2020).

[14] P Dillenbourg. *Collaborative learning: Cognitive and computational approaches. advances in learning and instruction series*. lsevier Science, Inc., 1999.

[15] D. H. Dolmans and H. G. Schmidt. "What do we know about cognitive and motivational effects of small group tutorials in problem-based learning?" In: *Advances in health sciences education, 11, 321-336.* (2006).

[16] D. Harmon and S. Erskine. *Eurostudent Survey VI.* 2017. URL: `https://9thlevel.ie/wp-content/uploads/HEA-Eurostudent-Survey.pdf` (visited on 10/14/2023).

[17] E. Hegarty-Kelly and D. A. Mooney. "Analysis of an automatic grading system within first year computer science programming modules". In: *Proceedings of 5th Conference on Computing Education Practice* (2021).

[18] K. J. Herrmann. "The impact of cooperative learning on student engagement: Results from an intervention." In: *Active learning in higher education, 14(3), 175-187.* (2013).

[19] El Said G. R Hone K. S. “Exploring the factors affecting MOOC retention: A survey study.” In: *Computers Education, 98, pp.157-168.* (2016).

[20] T. Jain and M. Kapoor. “The impact of study groups and roommates on academic performance.” In: *Review of Economics and Statistics, 97(1), 44-54.* (2015).

[21] G. M. Johnson. “Online study groups: Reciprocal peer questioning versus mnemonic devices”. In: *Journal of Educational Computing Research* (2006).

[22] Heiberger G. Junco R. and E. Loken. “The effect of Twitter on college student engagement and grades.” In: *Journal of computer assisted learning, 27(2), 119-132.* (2011).

[23] Nelson K. Kahu E. and C. Picton. In: ().

[24] N. Kara. “Enablers and barriers of online learning during the COVID-19 pandemic: a case study of an online university course.” In: *Journal of University Teaching & Learning Practice* (2021).

[25] C. W. Nam and R. D. Zellner. “The relative effects of positive interdependence and group processing on student achievement and attitude in online cooperative learning.” In: *Computers Education, 56(3), 680-688.* (2011).

[26] S. O’Neill and A. Mooney. “Developing a Collaborative Learning Application to Support Effective Student Collaboration in Hybrid Learning Environments”. In: *EDULEARN23 Proceedings, pp. 4931-4936.* (2023).

[27] S. O’Neill and A. Mooney. “Introducing a collaborative learning strategy in a hybrid and traditional laboratory for undergraduate computer science students.” In: *9th International Conference on Higher Education Advances (HEAd’23)* (2023).

[28] S. O’Neill and A. Mooney. “Investigating the Impact of Collaborative Learning on Undergraduate Computer Science Students”. In: *EDULEARN23 Proceedings, pp. 4986-4992.* (2023).

[29] V Patterson and N Prendeville. *A Study of Progression in Irish Higher Education Institutions 2010/11 to 2011/12*. Tech. rep. Higher Education Authority, 2023.

[30] A. C. Punnoose. "Determinants of intention to use eLearning based on the technology acceptance model." In: *Journal of Information Technology Education: Research* (2012).

[31] E. Péter, K. Gábor, N. Zsolt, and Lenke M. "The comparison of impact offline and online presentation on student achievements: A case study." In: *9th International Convention on Information and Communication Technology, Electronics and Microelectronics (MIPRO)* (2016).

[32] Rienties B. Khoja S. A. Rizvi S. "The role of demographics in online learning; A decision tree based approach." In: *Computers Education, 137, 32-47.* (2019).

[33] López M. I. Luna J. M. Ventura S. Romero C. "Predicting students' final performance from participation in on-line discussion forums." In: *Computers Education, 68, 458-472.* (2013).

[34] S. M. Rybczynski and E. E. Schussler. "Student use of out-of-class study groups in an introductory undergraduate biology course." In: *CBE—Life Sciences Education, 10(1), 74-82.* (2011).

[35] G. Sadykova. "Mediating knowledge through peer-to-peer interaction in a multicultural online learning environment: A case study of international students in the US." In: *International Review of Research in Open and Distributed Learning* (2014).

[36] P. Sander and J. de la Fuente. "Undergraduate student gender, personality and academic confidence." In: *International Journal of Environmental Research and Public Health, 17(15), 5567.* (2020).

[37] Cristea A. I. Toda A. M. Shi L. and W. Oliveira. "Social engagement versus learning engagement an exploratory study of Futurelearn learners." In: *14th International Conference on Intelligent Systems and Knowledge Engineering (ISKE) (pp. 476-483). IEEE.* (2019).

[38] Barbara Smith and Jean MacGregor. "What is Collaborative Learning?" In: *Washington Center for Improving the Quality of Undergraduate Education* 7 (1993).

[39] Sheppard S. D. Johnson D. W. Smith K. A. and R. T. Johnson. "Pedagogies of engagement: Classroom-based practices". In: *Journal of engineering education, 94(1), 87-101.* (2005).

[40] E Stacey. "Collaborative learning in an online environment." In: *Journal of Distance Education, 14(2), 14-33* (1999).

[41] A. S. Sunar, S. White, N. A. Abdullah, and H. C. Davis. "How learners' interactions sustain engagement: A MOOC case study". In: *IEEE Transactions on Learning Technologies* (2016).

[42] J. Tessier. "Small-group peer teaching in an introductory biology classroom." In: *Journal of College Science Teaching, 36(4), 64.* (2007).

[43] A. Tulaboev and A. Oxley. "A case study on using web 2.0 social networking tools in higher education." In: *International Conference on Computer & Information Science (ICCIS)* (2012).

[44] R. Vrioni. "Effects of group learning on the academic performance of university students." In: *Problems of Education in the 21st Century, 33(1), 111-117.* (2011).

[45] L Vygotsky. *Interaction between learning and development*. Linköpings universitet., 2011.

[46] K. R. Wentzel and D. E. Watkins. "Peer relationships and collaborative learning as contexts for academic enablers." In: *School Psychology Review, 31(3), 366-377.* (2002).

[47] S. Williams. "Engaging and Informing Students Through Group Work". In: *Psychology Teaching Review, 17(1), pp.24-34.* (2011).

[48] Zdrahal Z. Nikolov A. Pantucek M. Wolff A. "Improving retention: predicting at-risk students by analysing clicking behaviour in a virtual learning environment." In: *Proceedings of the third international conference on learning analytics and knowledge (pp. 145-149).* (2013).

[49] X. Yang. "A Historical Review of Collaborative Learning and Cooperative Learning". In: *TechTrends* (2023).

[50] Meng Y. de Pablos P. O. Zhang X. and Y. Sun. "Learning analytics in collaborative learning supported by Slack: From the perspective of engagement." In: *Computers in Human Behavior, 92, 625-633*. (2019).