Developing Arleno, an Open-source Learning Tool to Engage Learners Collaboratively and Critically in Text-based Learning Materials: A Design-based Research Study

Joe Appleton, BSc (Hons)

September 2022

This thesis is submitted in partial fulfilment of the requirements for the degree of Doctor of Philosophy

Department of Educational Research
Lancaster University, UK

This thesis results entirely from my own work and has not been offered previously for any other degree or diploma.

The word count for this thesis, excluding references, is 47,258.

Signature .....

Abstract

This thesis presents the outcomes of a three-year design-based research (DBR) project that addressed, through a pragmatic approach, the growing challenge of encouraging higher education students to engage deeply in text-based resources. In doing so, I took the novel approach of bringing together my skills as a researcher, programmer, and teacher to develop and evaluate an open-source, web-based learning tool called Arleno. The tool allows a teacher, through social annotation, to turn static text-based content into dynamic inquiry-based activities that can support a critical Community of Inquiry. I evaluated and enhanced the solution over two 12-week interventions in my direct practice setting, the computing department of a UK-based university. I underpinned this process with a qualitatively focused simultaneous mixed-methods approach that evaluated 50 activity answers, 24 semi-structured interviews, and field notes.

The findings revealed that developing a new learning tool is a challenging undertaking and uncovered a range of factors that need to be considered. However, the solution proved effective in supporting learners in taking a deep-level approach to engaging in text-based learning materials, supporting high levels of cognitive presence. Further, the participants, having had little meaningful prior exposure to group or text-based learning, reported increased motivation and criticality towards engaging in text-based materials. Overall, the results allowed deep insights regarding the design, the process, and the outcomes of creating an innovative learning solution that can support a critical Community of Inquiry. As such, this work will be of use to teachers, researchers, and learning designers who are looking either to design their own learning solution; or, for those interested in using the solution presented in this work and since Arleno is open-source they are free to do so.

Contents

Acknowledgments

This has been a long, gruelling process, and I could not have completed it without some exceptional people I would like to thank:

My partner Jane, for the past 20 years, you have always offered unfaltering support: proofreading my work, being a sounding board for what is certainly a dry topic and offering emotional support. I love you very much.

My two children, Ava and Arlo, were not born when I started this project! I love you both more than you will ever know.

My parents, Lee and Angie, your work ethic and support showed me what is possible.

My work colleagues Martin and Jennifer for making this process more bearable. Jennifer for your support and encouragement to take a PhD. Martin, for your light-hearted chats and cynicism, were welcome relief to this painstaking process.

My supervisor Natasa, I always felt inspired, energised, and motivated after speaking to you. Maintain your passion and energy for teaching and learning.

All my fellow PhD students in cohort 11 for turning what would have been a lonely pursuit into a fun group undertaking. I look forward to seeing you all progress through this process.

List of Figures

List of Tables

Chapter 1: Introduction

I work as a lecturer in the computing department of a United Kingdom (UK) based university. Before academia, I had a ten-year career as a programmer. This research brings together my roles as a lecturer and programmer to focus on the challenge of encouraging higher education (HE) students to engage in text-based learning materials. It is underpinned by my pragmatic belief that understanding and describing this problem is not enough; rather, I look to create learning solutions.

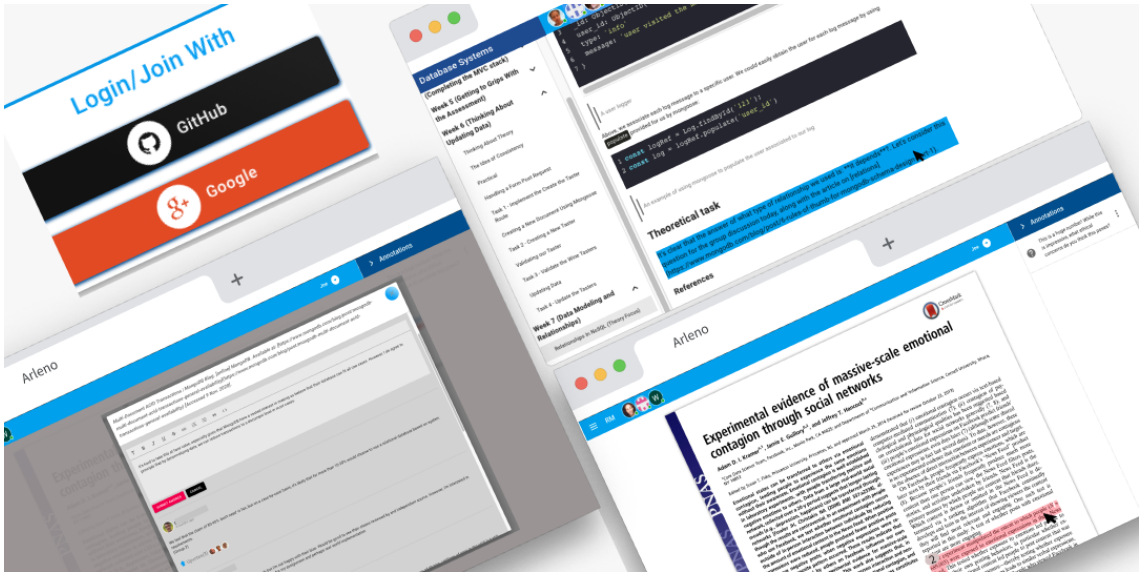

Figure 1.1: Collage snapshots of Arleno. An open-source SA tool and content management system: one of the practical outcomes of this design-based research.

In this introductory chapter, I lay the context that led me to address my pragmatic motivations through a three-year design-based research (DBR) project to develop a solution to engage HE students in text-based learning materials through a Community of Inquiry (CoI) (Garrison et al., 1999). The outcome of this process is an open-source, web-based learning tool called Arleno (see Figure 1.1). Arleno is free to use in any learning setting and addresses the study's aim in

two ways. First, it allows teachers to present text-based learning materials, comprising teacher-created notes and third-party readings, in a usable and accessible way. Second, it engages learners through enabling group inquiry-based social annotation (SA) activities to be attached to sections of the text-based content, engaging learners in the content. Overall, this represents a learning solution that not only engages students in text-based learning materials, but also supports a CoI which hones a learner's ability to think and act critically.

1.1 Context Behind the Research

The motivation to undertake this research stems from my experience of transitioning from an industry role to working as a lecturer in the computing department of a teaching-intensive, UK-based university. I made this transition seven years ago; in doing so, I have had to navigate many challenges; one of the most prominent has been my learners' lack of critical engagement with text-based resources.

Like most lecturers, I create and curate text-based resources, such as teacher-created notes and more traditional third-party readings, to assist students in their learning journey. Often, learners would fail to engage with these resources; at best, my impression was that they took what Marton and Säljö (1976) describe as a surface-level approach towards engaging with the material. When taking a surface-level approach, learners will often skim-read the resource and accept the contents at face value; this is converse to what Marton and Säljö call a deep-level approach. Learners taking a deep-level approach make meaningful connections between their existing knowledge to interpret and critically evaluate text-based learning materials. This distinction between a deep- and surface-level approach formed the basis for this study's aim; in other words, I endeavoured to design a learning solution that can take HE students from a surface- to deep-level approach towards engaging in text-based learning resources.

1.1.1 Students' Engagement in Text-based Learning Materials

While I observed students not engaging in text-based learning materials in my direct practice setting, this is not a localised problem. For instance, after surveying

208 undergraduate students attending a traditional UK-based university, St Clair-Thompson et al. (2018) concluded that students read for on average 14.1 hours a week, which is "substantially less than university expectations" (p. 195). The outcomes noted by St Clair-Thompson et al. may be a best-case scenario. Studies by Hoeft (2012) and Berry et al. (2010) present significantly worse levels of engagement. Berry et al. surveyed 264 undergraduate finance students across three US-based universities and found that 45% of students spend less than an hour on weekly reading and 17% acknowledged that they do not read. Similarly, Hoeft (2012) discovered just 45% of 111 US liberal arts students surveyed engage with reading materials. Interestingly, when Hoeft administered a reading comprehension test to the 45% of students who engaged with reading, only 55% showed a basic comprehension of the material they reported reading. Overall, these outcomes suggest that, regardless of academic discipline and learners' backgrounds, only a minority of undergraduate students read text-based materials in ways that meet the expectations of universities, and those that report engaging may not be taking a deep-level approach.

In considering why learners across HE are not engaging with text-based learning materials, the most cited reasons are lack of time and motivation (Starcher and Proffitt, 2011; Baier et al., 2011; Hoeft, 2012; Berry et al., 2010). For instance, Berry et al. (2010) found that students were aware of the importance of reading; however, most did not read because of social and paid work commitments limiting their time. Compounding this point, in a survey completed by 394 US-based, business undergraduate students, 48% of respondents cited lack of time as the reason for not completing readings (Starcher and Proffitt, 2011). Beyond time constraints, a lack of extrinsic and intrinsic motivators represent further reasons. For instance, in the previously mentioned survey conducted by Starcher and Proffitt, 26% of respondents reported they lacked the intrinsic motivation to read, finding engaging in text-based resources boring and irrelevant. However, this lack of motivation may have little grade impact. A survey of 395 US-based, business undergraduate students reported that 31.6% of respondents felt they could achieve an A grade without reading and 89.1% a C (Baier et al., 2011). Likewise, 74% out of the 264 of undergraduate finance students surveyed by Berry

et al. (2010) believed they could achieve a C grade or higher without reading. Overall, this suggests that if students are pressed for time or are not motivated to read, cutting back on reading may have little grade impact.

Above, I identified that the idea of HE students not engaging with text-based resources is widespread; further to this, there is evidence that it is a growing, unsolved problem. For instance, Baier et al. (2011), in finding that only 24.8% of 219 US undergraduate students surveyed acknowledged completing reading assignments, concluded that this lack of engagement is a growing problem "that warrants further investigation" (p. 392). Starcher and Proffitt (2011) made similar comments when attempting to understand why students do not engage with text-based learning materials. They concluded the problem was "significant" and called for more action. Therefore, I am contributing to a widely experienced unsolved problem.

1.2 Defining Deep-Level Engagement

At the start of this chapter, I established this study's aim focused on designing a learning solution supporting learners in taking Marton's (1988) deep-level approach towards engaging in text-based learning materials. In adopting Marton's (1988) idea of deep-level engagement to frame this study's aim, I challenged the traditional behaviourist view of engagement (Kahu, 2013). The behaviourist definition dominates HE discourse and focuses on how effective activity designs are at encouraging participation. However, measuring engagement on these terms overlooks how learners feel about the activities and how the outcomes form an association with their everyday lives. Trowler (2015) captures this idea, stating, "acting without feeling engaged is just involvement or even compliance; feeling engaged without acting is dissociation" (p. 15). In other words, a behavioural measurement of engagement cannot differentiate between a learner who is simply complying and one that is invested emotionally in the activity.

Deep-level engagement goes beyond the traditional behaviouristic view by considering learning as a process and an outcome. According to Marton (1988), "what is learned (the outcome or the result) and how it is learned (the act or the process) are two inseparable aspects of learning" (p. 53). For Marton and Säljö

(1976), a deep-level process involves learners directing their attention towards comprehending the meaning behind ideas represented in text-based content; in doing so, learners must think and act critically. In contrast, a surface-level process is where learners immediately accept, without question, the ideas represented in text-based content. This distinction between a surface- and deep-level approach to learning addresses the shortcomings of considering engagement solely through a behaviourist lens. For instance, a surface-level learner may well be behaviourally engaged in activities focused on text-based content; however, they may not be comprehending the deeper meaning of this content. As such, basing this study's learning solution on the aim of supporting, and qualitatively evaluating, deep-level engagement in text-based learning materials solves this problem. For learners to take a deep-level approach meant that participation by itself was not enough; rather, the solution had to support critical understanding and thinking as an outcome.

Operationalising Deep-Level Engagement

Above, I established the overarching aim of this study was to design a learning solution supporting students in taking Marton and Säljö's (1976) approach towards deep-level engagement in text-based resources. While Marton and Säljö's ideas capture a process and idealised outcome, they do not provide the means to operationalise deep-level engagement in the learning setting. To address this challenge, I used Garrison et al.'s (1999) CoI as a theoretical framing to guide the creation of the learning solution (see Chapter 2: Communities of Inquiry).

I was drawn to the CoI as it defines conditions to connect Marton and Säljö's (1976) idea of deep-level engagement to the outcomes of an online, text-based learning environment. A productive CoI consists of three presences: cognitive, teaching, and social. The framework presents a process where teaching and social presence interplay to support cognitive presence, with cognitive presence being the extent that learners have progressed through an idealised, four-step sequence of practical inquiry that results in deep-level engagement. An appealing aspect of the framework is Garrison et al. created a set of descriptors and indicators to direct the coding of the transcripts of text-based conversations to

determine the extent to which the content of the transcripts has progressed through the four-step sequence of practical inquiry. According to the outcomes of this process, my learning solution comprising inquiry-based SA activities, supported by Arleno, sustained high-level cognitive presence and therefore showed deep-level engagement took place, broadly meeting the study's aim.

Above, I have established the learning solution created for this study achieved high levels of cognitive presence, according to the outcomes of the PI textual analysis. Researchers often base the success of a given learning solution on this metric (see Sadaf et al., 2021). However, as I progressed through the DBR cycles, it became clear that the PI model, while providing a normative foundation, represents a narrow view of a CoI. It does not explore the qualitative nature of online interaction. Further, it does not reveal how critical understanding and thinking, supported by the solution, translate into learners' everyday lives. Finally, the coded, text-based transcripts only represented a small cross-section of the learning journey. Overall, it did not allow me to establish the extent the solution had supported critical understanding and thinking as an outcome beyond the text-based transcripts.

Given the limitations of solely using the PI model to determine deep-level engagement, I qualitatively expanded on what it means to engage deeply in text-based learning materials. I adopted a qualitatively focused mixed-methods approach to understanding the process, outcomes, and perceived future benefits that using Areleno to engage in inquiry-based SA activities supports. In doing so, I also used field notes to explore teaching presence. Furthermore, I interviewed learners to understand how social interaction worked for the purpose of inquiry and also the extent that they felt the learning solution improved their critical thinking, problem-solving and analytical abilities. Using this perspective, I considered all presences as factors for deep-level learning. Therefore, I viewed deep-level engagement as a social process that not only resulted in high levels of cognitive presence, but also supported learners with enhanced levels of critical inquiry that they will carry forward in their educational, work, and personal lives.

1.3 The Motivation to Encourage Deep-Level Engagement

In the previous section, I established deep-level engagement is a process that enhances learners' critical thinking and understanding as an outcome. Garrison et al.'s (1999) defines critical thinking as "essential metacognitive ability that encourages students to approach a problem strategically and actively seek out sources of knowledge, discover biases, sift through the increasingly large quantities of information now available, and formulate and defend their own intellectual positions" (p. 96). The motivations for designing a learning solution supporting deep-level engagement in text-based learning materials, therefore, went beyond enhancing reading compliance and expanded to developing learners' abilities to think and communicate critically. Within this section, I present the argument that designing such a solution has contributed to learners' employability and general life skills.

The ability to think critically is a fundamental graduate skill. Biggs and Tang (2011) even go as far to consider it the defining characteristic of what it means to be a graduate. For Biggs and Tang, "graduates are thought to feel a need to seek and evaluate evidence before coming to a conclusion, not to accept spin as readily as non-graduates, to question the status quo, to show intellectual curiosity" (p. 114). Therefore, the learning solution developed for this thesis supported a transferable skill that universities are expected to impart to their learners.

It is understandable criticality is a skill coveted by universities. The transferable nature of critical thinking means it is valued by employers. According to the UK Quality Code for Higher Education, critical thinking is a key transferable skill to enhance employability (QAA, 2018). Aligning with this sentiment, interviews conducted with UK employers revealed the ability to critically think as one of the core skills that employers look for in graduates (Lowden et al., 2011). However, Kornelakis and Petrakaki (2020) argue there are tensions between the neoliberal idea of students being the satisfied customer and teaching challenging skills, such as critical thinking, that employers are seeking. As such, the learning solution developed for this study looked to resolve these tensions and ensure learners' critical thinking skills are challenged.

Further to being an in-demand employability skill, critical thinking is

necessary in addressing the need to evaluate growing amounts of online information. The rise of the World Wide Web, specifically social media, has led to increasingly large quantities of easily accessible information. According to Bråten and Braasch (2017), individuals must have the ability to process and critically evaluate the credibility of this information. This is especially important, given the proliferation in fake news, there is now an ever-increasing difficulty in critically identifying the quality and truthfulness of information (Pennycook and Rand, 2021; Lacković, 2020). As such, supporting the development of a skill set that can allow learners to handle and critically evaluate possibly hundreds of pieces of information a day is a further important outcome of developing a learning solution that supports deep-level engagement in text-based materials.

1.4 Moving Towards a Solution

Above, I established that only a minority of HE students engage in text-based resources. Further to this, I framed the study's aim in designing a solution to support students in taking Marton and Säljö's (1976) deep-level approach towards engaging in text-based resources where critical thinking is honed and supported as an outcome. Within this section, I present the underlying ideas that led me to believe that the solution could lie in taking a socio-constructivist approach to reading.

A common approach to increasing student engagement with text-based resources is to connect the need to read to extrinsic motivators. For instance, Hoeft (2012) compared multiple engagement methods, including graded reading quizzes, graded diaries, and frequent reading reminders. They found that frequent reminders had no impact on self-reported compliance. However, in contrast, graded reading quizzes and reading diaries led to 74% and 95% of students reporting to comply with reading. At a glance, aligning reading to grade motivators seems effective; however, such an approach is troublesome for two reasons. First, as Starcher and Proffitt (2011) note, these methods are threatening students with embarrassment or a low grade; as such, they raise concerns surrounding efficacy. Second, such approaches, while increasing compliance, may not motivate learners to engage meaningfully. Indeed, referring back to Hoeft's (2012) study, when

reading comprehension tests were administered to the learners who reported they complied with reading, only half could show even basic levels of comprehension. As such, extrinsic motivators may only encourage students to take Marton and Säljö's (1976) surface-level approach towards engaging in text-based resources.

In addressing the shortcomings of the extrinsic, pressure-orientated approaches defined above, I aligned my solution to the idea that the best way to engage learners in text-based learning materials is through a collaborative, discursive approach. This proposition builds on Kerr and Frese's (2017) work that explored several ways to engage students in text-based resources and noted such an approach to be effective. They suggest planning activities that are run synchronously in class sessions that guide learners through reading and, in small groups, answering questions based on the contents of the reading. According to Kerr and Frese, conducting activities in this way "not only engages students but also allows the instructor to witness how students are synthesizing new information" (p. 3). Additionally, it is aligned with Garrison et al.'s (1999) socio-constructivist approach towards learning. According to Garrison et al., this intersubjective approach towards meaning-making leads to students taking Marton and Säljö's (1976) deep-level approach towards learning. As such, a socio-constructivist approach is aligned with this study's core aim of taking students from a surface- to -deep-level approach towards engaging in text-based learning materials.

1.5 The Need for a New Leaning Tool

Above, I established that I built this study on the hypothesis that activities based on socio-constructivist principles would engage learners deeply in text-based learning materials. However, these activities do not traditionally lend themselves to capturing the discussion process. A text-based computer-mediated communication (CMC) environment can solve this inconvenience by capturing the discussion process (e.g., a discussion board). Garrison et al. (1999) argues that communication structured in this way can be "preferable to oral communication when the objective is higher-order cognitive learning" (p. 90). Garrison suggests that text-based communication forces learners to slow down and think critically

about their communication.

In establishing a CMC environment, learning management systems' (LMS) discussion boards are widely used across HE settings (e.g., Brooks and Young, 2016; Cesareni et al., 2015; Commander et al., 2016; Jan and Vlachopoulos, 2018; Liu et al., 2018; Ragusa, 2017; Wei et al., 2015). However, using a discussion board to engage students in socio-constructivist activities based on text-based resources raises two concerns. First, studies suggest learners find LMS discussion boards hard to use and access (Gronseth and Hebert, 2019; Harris, 2017). They require multiple login steps and lack the features and usability of modern social-media discussion tools students have become accustomed. Second, learners must navigate back and forth between the text-based content and the discussion setting. In summary, there is a need for a usable CMC environment that situates the discussion alongside the readings in a more effective and user-friendly way than existing discussion boards used in higher education.

In addressing the concerns surrounding the usability of discussion boards, there has been a movement of educators repurposing social-media tools, such as Facebook and Twitter, to support collaborative learning (O'Dell, 2020; Davis, 2010; Tuhkala and Kärkkäinen, 2018). However, the use of such tools raises concerns surrounding data privacy, ownership, blurred boundaries, and depth of discussion (O'Dell, 2020; Davis, 2010; Tuhkala and Kärkkäinen, 2018; Zyto et al., 2012; Miller et al., 2018). There is also evidence that social media can negatively impact the mental health of its users (Pantic, 2014). Overall, while social media discussion tools solve the usability problems of LMS discussion boards, they are arguably not suited to educational use.

Social Annotation

In addressing the challenge of situating the discussion alongside the text-based material, a CMC technique known as social annotation has had some success. SA achieves this by designing activities that use web-based annotation tools to anchor the discussion outcomes to relating sections of the text-based content (Zarzour and Sellami, 2017; Shin et al., 2018; Chan and Pow, 2020; Gayoso-Cabada et al., 2019). Typically, an instructor will seed these discussions by annotating the text-based

materials with questions or discussion points (O'Dell, 2020). SA tools display the discussion outcomes in the margins of the text-based materials, anchoring the discussion to its related content.

While SA is an effective means to connect discussions to text-based learning materials, the tools to support this process present two limitations. First, the only SA tools designed with learning in mind appear to be Nota Bene and Perusall (Zyto et al., 2012; Miller et al., 2018). However, Purusall has a closed code-base, this means learning institutions cannot self-host, inspect, and control the data the tool gathers. NotaBene is open-source; however, its user experience, by the creator's own admission, is "very clunky" [1]. While commercial tools with annotation features can provide an enhanced user experience (e.g., Diggo, Google Docs), they raise the same privacy and data ownership concerns observed with the use of social media tools. Second, the common design choice of SA tools, including NotaBene and Purusall, is to support discussions in a small virtual margin alongside the reading material; however, this limits the depth and readability of the discussions (Sun and Gao, 2016; Chen and Yen, 2013). Overall, while SA solves the problem of discussions being situated away from the reading-material, this may come with a cost of lack of privacy, poor usability, and limited depth of discussion.

In addressing the problems identified above, there is a need to develop new, usable CMC environments designed to support in-depth discussions anchored to text-based learning materials. Furthermore, the learning institutions hosting these activities need ownership of the data. The CMC tool, Arleno, developed for this study, addressed these needs in four ways. First, it is open source, meaning the code-base can be audited, modified, and updated by any third-party developer. This allows for full transparency regarding how user data is processed. Second, an institution can choose to host the tool on their own internal servers. This gives complete ownership over the data and learner experience. Third, the SA activities the tool supports take place in a pop-over window, solving the issues regarding discussion depth. Finally, the modern design addressed the usability issues reported with existing learner focused SA tools.

[1] These comments were made by David Karger in a 2019 talk for Microsoft Research (https://youtu.be/LqAhQBDiwd0)

1.6 Research, Aim, Objectives, and Questions

1.6.1 Aim

Above, I established that the study's aim was to support HE students in taking Marton and Säljö's (1976) deep-level approach towards engaging in text-based materials through a critical CoI. Further, I have argued the need for an open-source solution that is built on sound socio-constructivist theory.

1.6.2 Objectives

In addressing aim, the following objectives were tackled, spanning empirical, theoretical, and practical concerns:

Empirical

- To further understand the problem of students not engaging in text-based resources.
- To understand students' attitudes towards group-based learning.

Theoretical

- To construct a conceptual framework grounded on the CoI that a SA-based CMC tool, designed to support learners in taking a deep-level approach towards engaging in text-based learning materials, can be based on.

Practical

- Based on the conceptual framework, to develop, evaluate, and refine a SA-based CMC tool and the associated activities through two semester-length interventions in my direct practice setting, a university computing department.

To address the above objectives, the following research questions have guided the research:

What are the learning opportunities, benefits, and challenges of developing an open-source learning tool, named Arleno, to engage HE

students in taking a deep-level approach towards text-based learning materials through group inquiry-based social annotation activities supporting a Community of Inquiry?

The primary research question is addressed through the sub-questions:

1. How was the design and development of the open-source learning tool, Arleno, managed?

2. To what extent did the outcomes of the group inquiry-based SA activities, facilitated by Arleno, support cognitive presence?

3. How did the educational affordances of Arleno's design support teaching presence in terms of the design, facilitation, and direct instruction of the group inquiry-based SA activities?

4. What were students' historic perceptions towards text-based learning materials and group work; and, in terms of text-based learning materials, how did the interventions change these perceptions?

5. What were students' perceptions and experiences of using Arleno in terms of the group inquiry-based SA process followed, the social presence supported, and the usability?

To answer the above questions, I adopted McKenney et al.'s (2006) DBR methodology to develop, design, and test the open-source SA inspired CMC tool Arleno and group inquiry-based SA activities based upon it. Two 12-week interventions with 50 and 75 participants taking second-year synchronous online modules in database programming and research methods framed the DBR process. Across these interventions, I conducted nine group inquiry-based SA activities that generated 50 answers. I evaluated the DBR process through a qualitatively focused mixed-methods design. In doing so, I brought together the outcomes of quantitative content analysis of the learning activities conducted, 24 semi-structured interviews, and analysis of my researcher and programmer field notes. Overall, this allowed me to shed light on the process, use, and outcomes of developing a learning solution.

1.7 Thesis Structure

The remainder of this thesis is structured as follows:

Chapter two presents the theoretical framework that guided this study's learning solution. I do this by progressing through decreasing layers of abstraction. I begin with the philosophical position that the best type of learning is socially constructed (Vygotsky, 1980). Next, I operationalise this position by establishing Garrison et al.'s (1999) CoI as the guiding framework for the study. I show how I used this framework to construct a learning solution scaffolding the practical inquiry process Garrison et al.'s (1999) prescribe to support a productive CoI. I close the chapter by showing how the pragmatic, solution-orientated approach I have taken contributes to underserved areas of research based on the CoI.

Chapter three explores the literature used to identify the features and theoretical underpinnings of a learning solution based on a newly created CMC tool supporting learners in taking a deep-level, collaborative approach towards engaging text-based learning materials. I begin by categorising the literature retrieved by study demographics and design. In doing so, I establish the methodological approach chosen for my study addressed several gaps in the literature. Next, I use Garrison et al.'s (1999) CoI to frame the modern CMC design principle that guided the learning solution created. Finally, I progress to studies surrounding SA that informed more granular, technical design choices. I, again, close this chapter by establishing my study's contributions against a backdrop of the existing literature.

Chapter four explores the DBR research design adopted for this study (Reeves, 2006). I begin by establishing how it is based on a pragmatic philosophical position (Dewey, 1933). Next, I progress on to how I deployed a DBR-based methodology to design, develop and test, over two 12-week interventions, a new learning tool named Arleno that supported group inquiry-based SA activities. Overall, I argue how a qualitatively focused simultaneous mixed-methods approach that evaluated 50 activity answers, 24 semi-structured interviews, and my programmer field notes cast a unique lens on the process and outcomes of developing this new learning solution.

Chapter five is the first of two findings chapters. It presents a design

narrative that includes evidence that the interventions supported high levels of cognitive presence (Garrison et al., 2001). The design narrative explores how I conducted the two DBR micro-cycles. I cover aspects such as the technical and design challenges of creating a new learning tool and delivering collaborative learning activities in an online setting. Overall, I show how an individual can assume the role of, programmer, researcher, and teacher to design, test, and evaluate a new learning solution.

Chapter six, the second of the two findings chapters, explores the interventions from the participants' perspectives. In doing so, I present the thematic analysis of 24 participant interviews. I describe seven themes exploring students' perceptions of using the Arleno to support group inquiry-based SA activities and the inquiry process followed. I present the idea that Arleno and the group inquiry-based activities it supported were well received. Further to this, I reveal that students largely followed a productive inquiry process, increasing their reported levels of criticality and appreciation of text-based resources.

Chapter seven aligns the findings presented in the previous two chapters to wider CMC research. I establish that the learning solution constructed for this study supported notably high levels of cognitive presence. I attribute the levels of cognitive presence to the solution supporting significant levels of social presence (Garrison et al., 2001). I go on to present the idea that the levels of social presence result from effective perception-action coupling, guiding learners towards meaningful social interactions (Kirschner et al., 2004). I close the chapter by establishing design recommendations spanning the technical, theoretical, and practical aspects of learning solution design.

Chapter eight brings this work to a close by presenting the conclusions and recommendations emerging from the research. I begin by revisiting the primary research question, using it to summarise the findings. Next, I move to establish contributions spanning the technical, theoretical, and practical concerns of socio-constructive learning solution design and development. Finally, I close this chapter, and the study, by presenting this study's limitations and recommendations for future research.

Chapter 2: Communities of Inquiry

As stated above, the aim of this study was to design a solution to take HE students from a surface- to a deep-level approach towards engaging with text-based learning materials (Marton and Säljö, 1976). Within this section, I sketch out the theoretical framework that guided the creation of this study's learning solution. I start by exploring how I grounded the framework on the philosophical position that learning is socially constructed (Vygotsky, 1980). Next, I present how Garrison et al.'s (1999) CoI was used to operationalise this socio-constructivist foundation.

2.1 Social Constructivism

The aim of this study was addressed through the introduction of a SA inspired learning solution into my practice setting. It was grounded in the idea that the best type of learning takes place between the social interactions and collective reasoning of individuals. Vygotsky's (1980) theory of social constructivism is well placed in capturing this idea and acts as a foundation to the wider theoretical framing.

Social constructivism is a variety of constructivism. Constructivism can be traced back to 1710 and the ideas of Giambattista Vico. It is based on the concept that humans construct knowledge through experiences and interactions with the world. Its use as a learning theory is widely credited to Piaget and Vygotsky (Bodner, 1986; Laurillard, 2013); however, there are subtle differences between their two interpretations. Piaget builds on the idea of constructivism, suggesting that learning takes place through individuals developing internal schemas to process experiences (Pintrich et al., 1993). For Piaget, new experiences conflict with existing schemas and assimilation must occur. As such, learning takes place through the continuous cycle of conflict and resolution. Vygotsky's (1980) theory of social constructivism differs to Piaget's ideas in that knowledge is constructed

through the collective interpretations of individuals. For Vygotsky, learning is therefore a group activity. While Piaget does acknowledge group learning, group members serve the purpose of triggering conflict and individual schema resolution. Further to this, Piaget states that individuals should be of similar ability. Unmatched abilities could lead to less authoritative group members agreeing as opposed to engaging in conflict and resolution. Vygotsky (1980), however, believes that learners are capable of doing much more under the guidance of more experienced individuals. The extent to which learners can achieve with the guidance of more experienced individuals is known as the zone of proximal development (ZDP). The ZPD is the idea that an individual's ability can be defined as their own developmental skills combined with that of more able students or teachers in a group. In summary, the ideas of learning being a collaborative outcome and more experienced learners supporting those with less knowledge are the fundamental differences between constructivism and social constructivism that underpinned the learning solution presented in this thesis.

2.2 Communities of Inquiry

Vygotsky's (1980) idea of socially constructivism describes the type of learning that the learning solution created for this study supports. I view the learning solution created as a tool that allows the anchoring of social constructed knowledge to choice pieces of text-based course content. To operationalise these ideas into practice, the guiding framework for this study has been Garrison et al.'s (1999) CoI.

Garrison et al.'s (1999) CoI was well aligned with the goals of this study, offering clear guidance on social constructivist learning mediated by technology. Garrison et al. developed the framework to enable critical discourse and thinking amongst HE learners in an online or hybrid setting. It describes a process whereby students engage in critical discourse through a text-based discussion environment (e.g., a discussion board). For Garrison et al. (2001), "a community of inquiry is an extremely valuable, if not essential, context for higher-order learning" (p. 7). It supports a process of sustained reflection through learners discursively externalising ideas and experiences. Overall, this process supports what Garrison

et al. refer to, interchangeably, as deep and meaningful learning or higher-order learning. According to an article co-written by Garrison (Akyol and Garrison, 2011), deep and meaningful learning is based on the ideas of Marton and Säljö's (1976) deep-level learning and can support high levels of criticality. As such, the CoI aligned with this study's aim of supporting HE students in taking a deep-level approach towards engaging in text-based materials.

To support deep learning, Garrison outlines that a successful CoI must consist of three interlinking presences: cognitive, social, and teaching. According to Garrison et al. (2000), "all three elements are essential to a critical community of inquiry" (p. 9) Below, I explore these three presences.

2.2.1 Cognitive Presence

According to Garrison et al. (2001), cognitive presence is "the extent to which learners are able to construct and confirm meaning through sustained reflection and discourse in a critical community of inquiry" (p. 5). Cognitive presence embodies the outcomes of the CoI where community members' private worlds are discussed and reflected upon to create a shared world. According to Garrison et al., the reconciliation of private and shared worlds are "crucial" in supporting cognitive presence.

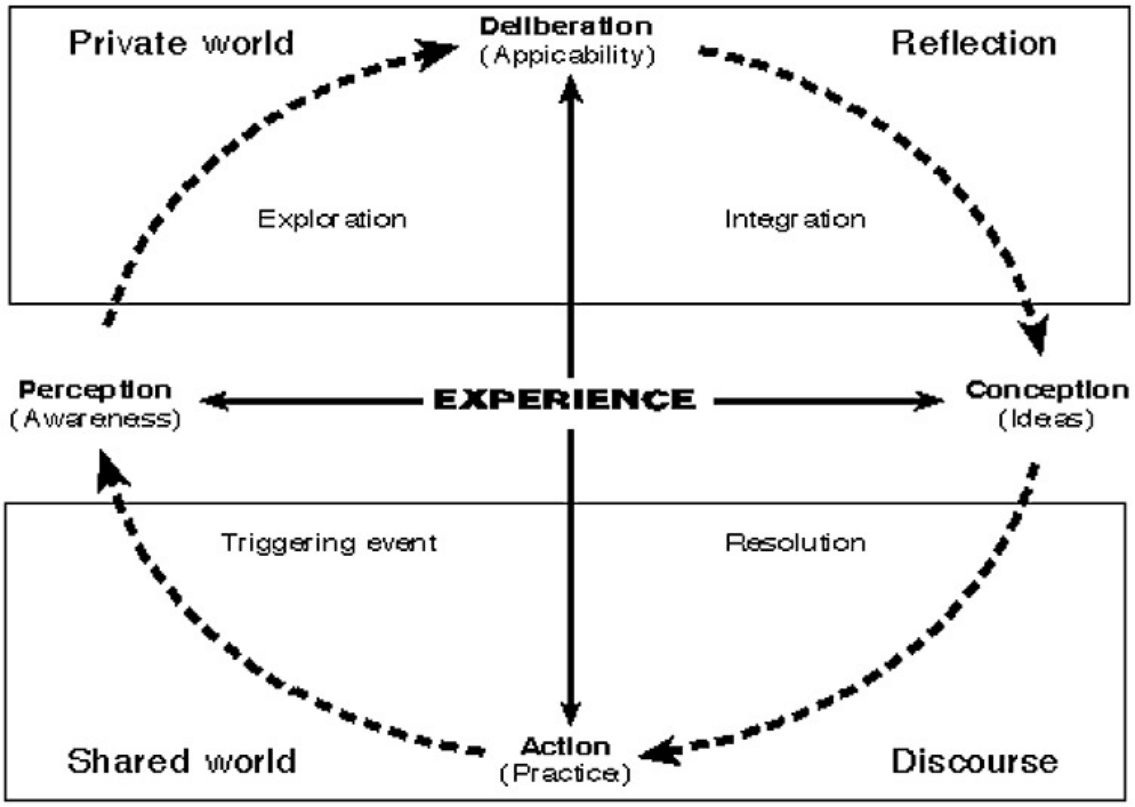

Figure 2.1: The practical inquiry model.

Garrison et al. (2001) operationalise cognitive presence through what they refer to as the practical inquiry model (PI). The model (see Figure 2.1), based on Dewey's (1933) ideas of inquiry, is built around two axes, which Garrison et al. refer to as "dimensions". Action–deliberation forms the vertical axis, and perception–conception the horizontal. The deliberation-action dimension connects shared and personal worlds; it signifies private reflection feeding into inter-student discourse. The perception–conception axis represents the "transition between the concrete and abstract worlds" (Garrison et al., 2001, p. 9). For Garrison et al., this transition involves synthesising ideas into meaning. The intersection of the two axes creates four quadrants that represent an idealised sequence of inquiry phases learners progress through:

- trigger: the event which prompts learners to engage in the inquiry process.
- exploration: experiences and ideas are externalised, discussed, and respectfully deliberated.
- integration: experiences are collectively formulated into new ideas or

concepts.

- resolution: ideas are agreed on, and action can then be taken based on democratically deliberated ideas which are then integrated into practice, completing the process.

The above PI phases essentially represent increasingly advanced levels of criticality. According to Garrison et al. (2001), the challenge is supporting learners in progressing past the relative comfort of the exploration phase towards the more demanding integration and resolution phases. With this in mind, I designed Arleno and the group inquiry-based SA activities based upon it to guide learners towards reaching the later integration and resolution phases of inquiry. This was conceptualised through the affordance of Arleno allowing for inquiry focused questions to be embedded into related sections of text-based content. The questions acted as a trigger, used to evoke group discourse focused on finding an answer. Finally, Arleno progressed the learning community towards integration and resolution by allowing answers to be captured and shared. Overall, this design guided students to notably high levels of cognitive presence.

Above, I established that the learning solution presented in this study supports high levels of cognitive presence. This claim can be made as an appealing aspect of the CoI is that Garrison et al. (2001) provides indicators to determine the stage of inquiry learner created text-based discussion has reached. A widely adopted approach is using the indicators to perform quantitative content analysis on the text-based discussion outcomes. A recent systematic review retrieved 30 studies conducted between 2000 and 2019 that focused on cognitive presence (Sadaf et al., 2021). Of these studies, 25 used content analysis underpinned by Garrison et al.'s PI indicators. Interestingly, only five studies combined content analysis with interviews and fewer used teacher reflections. The research design for this study addresses these unserved areas of inquiry. I combined quantitative content analysis with interviews and researcher, teacher, and programmer reflections. In doing so, I interlinked levels of cognitive presence to the subjective experiences of the learning community.

2.2.2 Social Presence

In the previous section, I established that cognitive presence embodies the outcomes of the CoI where private worlds are reflected upon and collectively shared to create new knowledge; however, it cannot exist without social presence. Social presence is the extent to which learners can project their ideas and values onto an online learning space. It is, in effect, a measure of the sense of belonging and freedom of expression that an online discussion environment offers. Overall, without social presence, students cannot externalise experiences and construct knowledge through the process of practical inquiry. Demonstrating this point, Garrison et al. (2010) used the validated CoI survey instrument, completed by 287 students, to show that social presence mediates students' perceptions of effective cognitive presence. The results are like those reported by Lee (2014) that showed, using quantitative content analysis and interviews, a positive correlation between social and cognitive presence. Social presence is, therefore, a vital component of the learning setting, and it must be carefully considered in the design process of creating a learning solution.

Above, I establish to support social presence, an online learning environment's design must support a sense of belonging and allow for freedom of expression. However, as I demonstrate in my exploration of the literature surrounding CMC in HE, the widespread use of online LMS discussion boards as the online setting does not provide the vital components required for social presence. Students have reported such environments hard to access and lack the modern features of social media platforms that they have become accustomed to (Gronseth and Hebert, 2019; Harris, 2017). I positioned my study to address these observed shortcomings. Arleno, the discussion environment developed, incorporated features inspired by social media platforms. The resulting tool is quick to access and allows learners to upload a profile picture. These profile pictures allow the connection of learning interactions with real people. Overall, these design choices addressed the perceived lack of social presence observed with discussion boards.

2.2.3 Teaching Presence

Garrison's model accounts for learning design through the function of teaching presence. Teaching presence is responsible for maintaining both the social and cognitive functions of the CoI (Garrison et al., 2010). As such, it is arguably the most important aspect of the theory. Garrison splits teaching presence into three sub-areas of concern: direct instruction, facilitation, and design. Design represents the development of suitable learning activities whereby students feel comfortable to socially interact. Facilitation is the process of contributing expert knowledge and experiences to the learning community. Both students and instructors can be facilitators; however, the role of direct instruction is the primary responsibility of the teacher. Direct instruction requires the instructor to guide the discourse in ways that cognitive presence is achieved and maintained. As such, teaching presence is the precursor and moderator of an effective CoI.

Despite its importance, few studies provide practical guidance on ways to establish teaching presence within a CoI. Garrison and Arbaugh argued in 2007 that there is a pressing need to document practical strategies and guidelines for establishing teaching presence (Garrison and Arbaugh, 2007). However, a recent study is built on the observation that there is still a "void" of research that documents design concerns surrounding teaching presence (Fiock, 2020). As such, the study presented in this thesis further contributes towards addressing this void by using programmer and teacher reflections to document the design and delivery of a learning solution that supported high levels of cognitive and social presence.

2.2.4 Applying Communities of Inquiry to Design-based Research

I applied the CoI in the context of a study following a DBR methodology to iteratively design, develop, and test a learning solution. The CoI is well suited to this application, providing guidance on learning designs that promote a socio-constructivist approach towards supporting critical thinking. Further to this, it can be used to diagnose issues surrounding the solution's use in the learning setting. For example, Swan et al. (2014) used the CoI to guide a DBR project developing an online postgraduate education course. They noted how viewing the resulting process through the lens of the CoI allowed "iterative tweaking" of the

course design (p. 79). In a further example, Posey et al. (2014) used the CoI to examine different learning activities that formed part of the wider learning environment. According the authors, the CoI provided them with valuable insights on how specific activities can support the wider educational experience. Overall, these examples show that the CoI is capable of underpinning course and activity level designs across DBR projects

Above, I have established CoI is a versatile framework offering both normative and evaluative functions. On closer inspection, it appears that my study, applying the CoI to design and test a learning solution in a computer science setting, is a novel use of the framework. A systematic review locating 103 studies, based on the CoI, highlights this point: just four of these studies focused on computer science settings, only two evaluated specific tools or resources that supported the learning experience, and none used the CoI to guide the creation of a new tool (Stenbom, 2018). As such, using the CoI to create and test, in a computer science setting, a learning solution based on the construction of a new learning tool is a lightly explored use of the framework.

2.2.5 Limitations of Communities of Inquiry

Overall, I found the CoI to be well suited to this project. However, there were limitations surrounding the ideas of cognitive and teaching presence that needed to be considered. To recap, cognitive presence sustains learning in an online environment; however, if learning is interpreted as an outcome and not a process, the CoI is arguably not effective. A popular systematic review by Rourke and Kanuka (2009) concluded "that it is unlikely that deep and meaningful learning arises in CoI". The conclusion was reached after reviewing 252 studies framed through the CoI. According to Rourke and Kanuka (2009), only five of these studies measured learning. Further to this, the instruments used to measure learning were self-administered surveys capturing students' perceptions of learning. As such, the only evidence that the CoI supports learning is based on the limited subjective accounts of students. Akyol et al. (2009) directly counter this claim, stating that the framework supports "how we construct knowledge as opposed to an objectivist focus" (p. 124). Indeed, the idea that the theory does not support

generalisable knowledge aligns to Garrison et al.'s (2001) earlier ideas suggesting that "judging the quality of critical thinking as an outcome within a specific educational context is the responsibility of a teacher" (p. 2). With this in mind, I adopted a mixed-methods approach that focused on both the learning process and cognitive outcomes supported.

I found Garrison et al.'s (2001) ideas surrounding teaching presence presented further limitation to the theory. Teaching presence is subdivided into design, direct instruction, and facilitation; however, the lines between the ideas of direct instruction and facilitation are blurred. On the one hand, Garrison et al. (1999) state that direct instruction should be kept to a minimum. On the other, both students and instructors are encouraged to contribute to the conversation in the form of facilitation. As such, it is open to interpretation when, or indeed if, facilitation can inadvertently become direct instruction. This limitation is further highlighted when considering studies through the lens of teaching presence. For instance, there are studies, such as the one by Khalid (2019), that report a high level of instructor participation. According to Khalid, teachers would "consistently log into the e-forum to read students' discussions and give their feedback or advice where needed" (p.8). In contrast, there are studies, such as the one conducted by Dugartsyrenova and Sardegna (2019), that align to the light touch approach that the CoI advocates. In this study, lecturers would only intervene when there were technical difficulties or unresolvable disagreements. However, both studies supported high levels of learning. As such, the level of direct instruction may well be dependent on the teaching context. In the case of my study, I chose to keep direct instruction surrounding the inquiry-based SA activities to a minimum. The goal was to, as much as possible, foster a sense of learner ownership of the discussion space.

2.3 Conclusion and Theoretical Contributions

This chapter has formulated a theoretical framework on which the learning solution to engage students deeply in text-based materials was based upon. In doing so, I have progressed through decreasing layers of abstraction, starting with the philosophical position that learning is socially constructed (Vygotsky, 1980); I

operationalised this position through Garrison et al.'s (1999) CoI. The CoI is a conceptual framework designed to engage HE students in taking Marton and Säljö's (1976) deep approach to learning in an online text-based setting; as such, it is well-aligned with my research aim. Overall, as the future chapters will show, this theoretical framework has enabled me to map sound socio-constructivist learning theory to the concrete implementation of a learning solution, evaluated in a real-world learning setting.

In constructing a theoretical framework centred on the CoI, I established that this study, through adopting a mixed-methods DBR approach, makes four notable contributions to the research community focused on Garrison et al.'s (1999) conceptual framework. First, most studies focus on measuring cognitive presence through qualitative content analysis. However, few combine content analysis with interviews and even fewer use teacher reflections. I address this underserved area by taking a mixed-methods approach that combines content analysis, researcher reflections, and semi-structured interviews. Second, despite teaching presence forming arguably the most crucial dimension of the CoI, there is a lack of studies revealing how to support this presence. By adopting a DBR methodological approach, I address this void by documenting the implementation and delivery of a learning solution. Further, I present pedagogical design recommendations based on the entirety of the DBR process. Third, there have only been limited examples of the CoI used in the computer science setting that forms the focus of this study. Fourth, the CoI is rarely used, like it is in this study, to guide the creation of a new learning solution. As such, in documenting the design process of creating and testing a learning solution underpinned by the CoI, I am presenting a novel application of the theory. Overall, I have shown the pragmatic solution-orientated approach of DBR has allowed for contributions to lightly explored aspects of CoI usage.

Chapter 3: Literature Review

As stated above, the overarching goal of this study was to design a solution to take students from a surface- to a deep-level approach towards engaging with text-based learning materials (Marton and Säljö, 1976). In approaching this goal, I chose to adopt a DBR methodology (McKenney et al., 2006). According to Herrington et al. (2007), the purpose of a DBR literature review is to "facilitate the creation of draft design guidelines to inform the design and development of the intervention that will seek to address the identified problem" (p. 8). Further to this, it should be used to identify ways in which the study can contribute a theoretical understanding to the problem space (McKenney and Reeves, 2012). With these ideas in mind, the literature review addressed two objectives:

- To guide the development of the open-source learning tool Arleno and group inquiry-based SA activities based upon it.
- To identify theoretical and empirical gaps in the literature and determine how to design a study that can address these gaps.

In addressing the above objectives, what follows is an exploration of studies reporting on CMC or SA in HE settings that support Garrison et al.'s (1999) ideas of collaborative inquiry. The solution based on this process, Arleno, bears more similarity with SA tools than wider CMC environments. However, looking at both SA and CMC allowed me to include design ideas that would have been otherwise missed by focusing on SA studies alone. Furthermore, it enabled me to construct overarching CMC principles that guided the study's learning solution.

3.1 Review Protocol

To ensure that studies were objectively retrieved, I developed a search protocol. Studies were only included if they met the inclusion criteria:

- The study took place in a HE setting.
- The study employed digital tools to support CMC environments or SA.
- The study presented empirical data.
- The article appeared, within the last 5 years, in a peer-reviewed journal.

To differentiate CMC and SA studies two separate search queries were developed:

1. **CMC** ("computer-mediated communication" OR "computer mediated communication" OR "text-based communication" OR "asynchronous communication" OR "online community" OR CMC) AND ("higher education" OR "HE" OR "university" OR "post secondary education")
2. **SA** ("collaborative annotation" OR "social annotation" OR "SA") AND ("higher education" OR "HE" or‘ "university" or "post secondary education"))

Using the above queries, searches of the academic databases Scopus and Science Direct were conducted. After removing duplicates, the search process resulted in 162 CMC and 71 SA studies. The inclusion criteria were then applied in two stages. First, each abstract and title were scanned, reducing the collection to 42 CMC and 46 SA articles. Next, each remaining article was read in full and a further 16 CMC and 23 SA articles were discarded. The process resulted in 49 articles (26 CMC and 23 SA). The articles were then read again, several times, and a data extraction sheet was developed, to categorise key study attributes. Studies were categorised according to geographic region (see Table 3.1), level of study (see Table 3.2), academic discipline (see Table 3.4), delivery (see Table 3.3), data collection methods (see Table 3.7), and study aims (see Table 3.6). Finally, the articles were then imported into NVivo and coded to generate themes surrounding learning benefits, features, pitfalls, and activity design of learning supported through CMC and SA. The CMC studies acted as overarching guidelines on how to support a CoI in HE and are presented through the lens of the CoI's presences. Whereas the SA studies served to guide the granular features of the learning solution and are grouped deductively into design focused themes.

To report on the outcomes of the above process, I start by summarising the key attributes across the entirety of the literature retrieved. Next, I move on to explore the themes generated for CMC and SA studies in the form of a narrative. To enhance the narrative surrounding the themes, commonly mentioned theories and authors have also been included.

3.2 Literature Summary

Location	CMC	SA	Total
Africa	0	2	2 (3.77%)
Asia	9	7	16 (30.19%)
Australia	5	0	5 (9.43%)
Europe	8	5	13 (24.53%)
North America	8	8	16 (30.19%)
South America	0	1	1 (1.89%)

Table 3.1: Studies categorised by geographic location of participants covered in the study.

Level	CMC	SA	Total
Undergraduate	22	19	41 (82.00%)
Postgraduate	5	1	6 (12.00%)
Uncategorised	0	3	3 (6.00%)

Table 3.2: Studies categorised by level of study.

Mode of Delivery	CMC	SA	Total
Blended	6	21	37 (75.51%)
Online	6	1	7 (14.92%)
Uncategorised	4	1	5 (10.20%)

Table 3.3: Studies categorised by mode of delivery.

Discipline	CMC	SA	Total
Social Science	0	1	1 (2.04%)
Education	8	5	13 (26.53%)
STEM	7	6	13 (26.53%)
Business and Law	2	1	3 (6.12%)
Health and Medicine	2	2	4 (8.16%)
Humanities	1	5	6 (12.24%)
Languages	0	2	2 (4.08%)
Uncategorised	6	1	7 (14.29%)

Table 3.4: Studies categorised by academic discipline.

3.2.1 Study Context and Participants

Categorising the literature by country, level of study, mode of delivery, and discipline revealed three underrepresented areas. First, much of the research into CMC and SA is conducted in North America ($n = 16$), Asia ($n = 16$), and Europe ($n = 13$). These three regions account for 85% of all studies retrieved. Of the remaining studies, five represent Australian participants, two represent African participants, and just a single study focuses on South American participants. Second, most studies focus on undergraduate students ($n = 41$) in a face-to-face setting ($n = 37$). Third, in terms of academic discipline, education represents a significant proportion of all studies ($n = 16$). Studies in an education discipline are the same in number as the entirety of the work reporting on science, technology, engineering, and maths (STEM) disciplines. Adding further perspective, in the academic year 2018 to 2019, 745,000 students studied STEM subjects in the United Kingdom; in comparison, only 143,000 students studied education-focused subjects (Mantle, 2020). Based on the above observations, my study, that took place online and in computer science context, addresses the lack of inquiry into online delivery models and participants taking a STEM education.

3.2.2 Design of Studies

Methods	CMC	SA	Total
Quantitative	9	10	19 (38.78%)
Qualitative	1	3	4 (8.16%)
Mixed Methods	16	10	26 (53.00%)

Table 3.5: Studies categorised by overarching methods chosen.

Study Aim	CMC	SA	Total
Measuring learning effects of tool/environment	4	10	14 (28.57%)
Learners' perceptions of tool(s)/environment	6	7	13 (26.53%)
Measuring how a tool(s)/environment effects learner attitude (e.g., motivation, self efficacy/compliance, or relatedness)	7	3	10 (20.41%)
Measuring factors influencing participation or community formation with tool/environment	6	1	7 (16.33%)
Investigating how students interact with tool/environment	1	1	2 (4.08%)
Institutional/Departmental case study of tool/environment	1	1	2 (4.08%)
Teachers' perceptions of tool/environment	1	0	1 (2.04%)

Table 3.6: Studies categorised by aim.

Methods Used	CMC	SA	Total
Surveys	12	9	21 (29.58%)
Quantitative/Qualitative analysis of discussions	9	9	18 (25.35%)
Pre- and post-tests/surveys	6	7	13 (18.31%)
Analysis of student records (e.g, assessment results and attendance records)	4	3	7 (9.86%)
Interviews and focus groups	1	3	4 (5.63%)
Social network analysis	1	2	3 (4.23%)
Analysis of analytics generated by tool/environnement (e.g., number of logins, time spent on system)	2	1	3 (4.23%)
Observations	1	1	2 (2.82%)

Table 3.7: Studies categorised by data collection tools used.

To guide the empirical design of my DBR study, studies were categorised by their methodological approach (mixed-methods, qualitative, or quantitative)(see

Table 3.5), and data collection methods (see Table 3.7). When considering methods, 56% of studies retrieved use mixed-methods ($n = 26$), 35% of studies used quantitative ($n = 26$), and only 8% used qualitative methods ($n = 26$). In terms of data collection specifics, surveys, analysis of the discussions, and pre- and post-tests accounted for 60% of methods chosen. Curiously, only four studies used focus groups or interviews to gain deep qualitative insights (Azmuddin et al., 2018; Harris, 2017; Olson and Brown, 2018; Clapp et al., 2021). Overall, there is a clear lack of qualitative inquiry providing rich participant perspectives; my study, in deploying semi-structured interviews as the primary data collection method, addresses this underrepresented area of inquiry.

3.2.3 Aims of Studies

To further guide the empirical design of my DBR project, studies were categorised by their aims (see Table 3.6). Measuring learning effect, gaining learners' perceptions, measuring effects on learners' attitudes, and determining factors influencing levels of participation formed the primary aim of 92% of the studies located. There are only two studies with the aim of exploring how learners interact with a CMC environment or SA tool (Dahl, 2016; Vinagre and Corral Esteban, 2018). In considering how these objectives inform study design, those that measure a SA or CMC environment's effect on learning or attitude overwhelmingly use pre- and post-tests or surveys. Interestingly, only three studies had the goal of measuring learning through a socio-constructivist lens (Commander et al., 2016; Gayoso-Cabada et al., 2019; Li et al., 2015). These types of studies view learning as socially constructed (Vygotsky, 1980), best measured through the depth and quality of discussion outcomes and social interactions. In summary, categorising the studies by aims indicates there is a lack of inquiry looking at the process of interacting with a SA or CMC environment and studies approaching learning through a socio-constructivist lens. In addressing these gaps, I have investigated the affordances and process of students using Arleno, the tool developed for this study, to support group inquiry-based SA activities though a socio-constructivist lens.

3.3 Computer Mediated Communication in Higher Education

Above, I explored the design and aims of CMC and SA studies; further to this, in the previous chapter, I established the learning solution developed for this study is based on Garrison et al.'s (1999) CoI. Within this section, I explore general CMC practices primarily through the teaching presence sub-function of design. Design considers how teaching, social, and cognitive presences are interlinked to support a functioning CoI. As such, what follows are the broad design principles that guided the way in which the implemented learning solution supported each presence.

3.3.1 Cognitive Presence

Cognitive presence represents the extent learners construct and confirm meaning through a CoI. The CoI is designed to function in a CMC environment; therefore, it is unsurprising the literature reveals that the decision to use a CMC approach in addressing this study's objective is well supported. According to a study by Harris (2017), both students and teachers found using CMC supported deep and meaningful learning experiences. Further to this, there is evidence to suggest that CMC can positively influence motivation (Butz and Stupnisky, 2017; Inel Ekici, 2018; Law et al., 2019; Yilmaz and Keser, 2016). For instance, Butz and Stupnisky (2017) assigned 83 American postgraduate business students to an experimental group using a discussion board, and a control group with no access to this board. Participants using the discussion board were significantly more motivated to form social connections with their peers. Underpinning the data regarding experience and motivation, is a body of quantitative evidence showing that CMC supports learning (Lee and Teh, 2016; Wakefield et al., 2018; Förster et al., 2018). For example, Alzahrani (2017) demonstrated that, over a 10-week period, the sample of 135 undergraduate teaching students that simply had access to an online discussion board increased grades relative to those that had no access. The above studies demonstrate that CMC can provide students with social connections and perspectives to approach this study's objective of engaging learners deeply in text-based learning materials through through a critical CoI.

Above, we have seen the CMC can support cognitive presence as outcome.

The principles that support this outcome are based on a collaborative constructivist view of learning (Vaughan et al., 2013). As such, the CMC environment must be considered in relation to the extent it can support socio-constructivist activities. According to Garrison et al. (1999), the best types of activities support the ongoing externalisation and discussion of ideas, practices, and experiences, and it appears the literature located validates this advice. For instance, Commander et al. (2016) used CMC to support discussions between Chinese and American students. Students were required to discuss case studies regarding the Chinese learning environment, relating them to their own experiences. Based on a relatively small sample of 289 comments, according to Gunawardena et al.'s (1997) interaction analysis model (IAM), 48% of discussion comments represented new knowledge construction. A further example is a study by Lee and Teh (2016) which focused on CMC discussion surrounding educational doctoral students' practice-linked project ideas. According to IAM, a remarkable 90% of the discussion outcomes represented knowledge construction. These examples demonstrate ways private worlds can be externalised and used to support discourse.

Above, we have seen examples of cognitive presence being supported by learners sharing private worlds through sustained discourse in a CMC environment. However, according to Vaughan et al. (2013), constructing an instructional experience that fosters a socio-constructivist approach towards learning is a challenging undertaking. This is particularly the case if, like my study, the learning community consists of undergraduate students. Unfortunatly the literature provides little in the way of guidance on how to best structure activities. From the limited information available, there is evidence that divisive discussion topics and scaffolding the discursive process is effective. For instance, a study by Dugartsyrenova and Sardegna (2019) encouraged Russian and American trainee teachers to share and breakdown controversial, common cultural stereotypes. The researchers noted this was an effective means of "intercultural knowledge and awareness" (p. 213). Further to this, scaffolding has been shown to be an effective means to support undergraduate learning communities. For example, Cesareni et al. (2015) presents ideas on how scaffolding can be used to

sustain meaningful online discussions. In this study, 143 Italian undergraduate education students were assigned roles to play in the discussions (e.g., Synthesiser and Sceptic). The researchers observed that students with roles engaged more in discussions. Interestingly, when the roles were taken away students who previously had roles continued to participate more in discussion. This suggests that motivators that begin external and extrinsic can internalise over time (see Vygotsky, 1980). Based on these insights, I designed the learning solution for this study to scaffold learners through Garrison et al.'s (2001) stages of practical inquiry. Further to this, where possible, I based the activities on divisive topics. Finally, by presenting a design narrative surrounding delivering the learning solution, I contribute to a lightly explored area of activity design and development.

3.3.2 Social Presence

Social presence is the extent that learners can project themselves onto a CMC environment as real people, allowing cognitive presence to form. In terms of CMC environments, the literature reveals the traditional discussion board is the overwhelming environment of choice (e.g., Brooks and Young, 2016; Cesareni et al., 2015; Commander et al., 2016; Jan and Vlachopoulos, 2018; Liu et al., 2018; Ragusa, 2017; Wei et al., 2015). Conveniently, discussion boards are built into most learning management systems (LMS). Furthermore, LMS systems are usually open-source and hosted by learning institutions, giving complete ownership and control over learners' data. Overall, it is clear that using the readily available LMS discussion board offers a convenient way to scaffold a CMC environment in a HE setting.

Given the successful use of discussion boards as CMC environments capable of supporting a critical CoI, an immediate question arises: why was there a need to base this study on creating a new CMC environment? While I considered building a learning solution based on a discussion board, I concluded that discussion boards do not support optimal levels of social presence. They are one of the earliest web-based CMC environments, and they have changed little in the two decades since Garrison et al. (1999) first advocated their use in HE. There is evidence to suggest that students now find the communication platforms provided by widely

used social networking and messaging platforms easier to use (Gronseth and Hebert, 2019; Harris, 2017; Stolaki and Economides, 2018). For example, Gronseth and Hebert (2019) conducted an intervention that used the mobile messaging service GroupMe to support social learning. Students commented that the messaging service was easier to use and presented fewer steps to access than a LMS discussion board. These results are similar to those reported by Tuhkala and Kärkkäinen (2018) who conducted a survey showing that 79% ($N = 24$) of masters' computing students preferred using the modern communication tool Slack over the traditional discussion board. In summary, the features offered by modern messaging tools can offer increased social presence and are a user-friendly alternative to the LMS discussion board.

While social networking messaging platforms present a modern and useable alternative to the LMS discussion board; using them in the classroom raises concerns regarding privacy and the extent they support cognitive presence. Researchers have argued that using social media tools may cross unwanted boundaries between learners' social and academic lives (O'Dell, 2020; Harris, 2017). Furthermore, several authors have suggested using for-profit platforms in the classroom raises concerns surrounding data ownership and privacy (Davis, 2010; Tuhkala and Kärkkäinen, 2018; O'Dell, 2020). From a learning perspective, there are also worries regarding the levels of cognitive presence social messaging platforms support. For instance, Lee and Teh (2016) found that students primarily used social messaging to share short pieces of information. Harmon and Tomolonis's (2019) study, comparing Facebook groups versus discussion boards, provides further evidence questioning the depth of discussion facilitated by social messaging platforms. They found conversations over Facebook versus discussion boards to be shorter, less focused, and demonstrate a faster decline in messaging frequency. Overall, these outcomes suggest that the high levels of social presence supported by social networking and messaging platforms may not necessarily support cognitive presence and gives rise to privacy concerns.

Above, I broadly categorised CMC environments as discussion boards or modern social media tools. I established that these environments sit at opposing ends of the social presence spectrum. Discussion boards can support high levels of

cognitive presence; however, their lack of perceived usability and accessibility may limit learners' abilities to project themselves onto the online environment, providing low levels of social presence. Conversely, social media tools offer high levels of social presence; however, they have been shown to present privacy concerns and do not necessarily support cognitive presence. Based on these observations, Arleno, the learning tool developed for this study, was based on three broad design aspirations:

1. To have the usability and accessibility of social media.
2. To support the depth of discussions of discussion boards.
3. To maintain the learning tool as an open-source project, allowing institutions to self-host and own the data it generates.

By basing a solution on the above design considerations, I created a learning tool that provided a crucial balance between the social presence offered by social media and the depth of discussion afforded by discussion boards. Moreover, the open-source implementation means that learning institutions can ensure data privacy and use the tool with no upfront costs. Overall, I addressed the need to create accessible, learning-focused CMC tools.

3.3.3 Direct Instruction

To this point, I have introduced the design principles underpinning learning and technical concerns of a CMC-focused learning solution. Within this section, I consider how direct instruction is applied to ensure the smooth running of this solution.

Direct instruction is the facet of teaching presence that ensures the CoI runs smoothly. While we have seen that CMC is an effective means for supporting learning, the literature suggests that its use can present barriers in the form of being perceived as a poor alternative to its face-to-face equivalent, students being grades motivated, and teacher over participation. It is the job of direct instruction to be aware of and counter these pitfalls. As such, what follows is an exploration of these pitfalls, alongside my design decisions to overcome them.

Learners may see an online setting as a poor alternative to its face-to-face equivalent. A survey distributed to 289 Australian distance education students showed that over 85% considered the online learning environment isolating, ineffective, and inferior to its face-to-face equivalent (Ragusa, 2017). Sentiments along the lines of "nothing beats the face-to-face communication with student/lecturers" (p. 7) were commonplace. Overall, the study concludes that online learning could be seen as a "poor cousin" (p. 20) to its face-to-face alternative. Likewise, a survey completed by 595 American students found that online participants felt less connected and were less likely to engage than their face-to-face counterparts (Brooks and Young, 2016). This suggests that online learning may be at odds with traditional face-to-face delivery models. As such, by developing and evaluating a learning solution, delivered synchronously online, my study addressed the need to resolve the conflicts arising when delivering learning in an online setting.

A further barrier is that students may be grade focused and feel that collaborative learning advocated by the CoI and the discussion it entails may not serve their individualistic goal to get a high grade. For instance, Molinillo et al. (2018) noted that students overly focused on grades may not want to disagree with peers and engage in debate. Where students do want to engage, it may only be to win favour with teachers. For example, in a study conducted by Liu et al. (2018) an intervention resulted in 325 Chinese trainee teachers creating 10,870 discussion board posts. On closer inspection, students who achieved higher course grades posted significantly more than their low-achieving counterparts. However, both high- and low-level students had similar low levels of interaction. In other words, high-level students posted more frequently; however, they seemingly were only interested in appearing active, as opposed to engaging in meaningful discussion. Studies like these show that participation in an online setting can be misleading, and there is a need to develop methods to guide, rather than force, learners to participate in CMC. My study addressed this need by developing a learning solution that scaffolds undergraduate students through Garrison et al.'s (1999) PI phases, without the need to align discussion outcomes to grades.

We have seen that achieving deep and meaningful online discussions is a

challenging undertaking. As such, to support the discussion, teachers may play an overactive role and block inter-student discussion. This goes against the advice, presented in Garrison et al.'s (2000) CoI, that teachers should only participate in the discussion to mediate issues, keeping direct instruction to a minimum. However, it seems that some teachers may not be following this advice. For instance, in a study by Liu et al. (2018) instructor posted content accounted for over a third of the 304 postings. In a further study, Friess and Lam (2018) used the social network Twitter to host discussion. On analysis of the Tweets, the most retweeted were Tweets by the instructor. Further to this, the instructor was the most messaged individual amongst all participants. Overall, this shows that discussions can become teacher-student as opposed to inter-student focused. Mindful of this pitfall, I relied on the scaffolding provided by the developed learning solution to guide discussions rather than teacher intervention.

3.4 Social Annotation in Higher Education

Above, I explored how the literature informed the overarching design principles used to develop a learning tool grounded on the CoI (Garrison et al., 1999). Within this section, I consider how the design principles mapped to the granular implementation of the learning tool Arleno and the group inquiry-based activities it supported. This section positions this learning solution against the literature retrieved around SA.

3.4.1 Contemporary SA Tools Informing the Design of Arleno

Recent studies suggest that a wide range of tools are used to support SA in the learning setting. Tools vary between those that have an annotation feature as part of their wider feature-set (Yeh et al., 2017; Clapp et al., 2021), annotation tools developed for an isolated study (Olson and Brown, 2018; Azmuddin et al., 2020), tools designed specifically for educational SA use (Zyto et al., 2012; Miller et al., 2016), and commercial annotation tools repurposed for learning (Kalir et al., 2020; Li et al., 2015; Sun and Gao, 2016). All of these tools have a similar base-level of functionality. They allow teachers and students to highlight web-based content and associate it with comments and questions. What follows is an exploration of

these tools in the context of how they informed the design of Arleno.

SA tools designed for educational use are in the minority; Nota Bene and Perusall appear to be the only active projects. Nota Bene is developed and maintained by MIT researchers and is open-source (Zyto et al., 2012). Perusall is the result of a Standford team of researchers' use of Perusall (Miller et al., 2018) and is a closed-source alternative. Given the connection between the two projects, both tools have similar learning-specific features. Participants can upvote and react to annotations (e.g., agree, disagree, and request more information) and be assigned to reading groups. Perusuall has a more advanced teaching toolset, allowing instructors to set and mark reading assessments. Demonstrating the demand for learning-focused SA tools, both have gained a steady momentum and form the focus of a growing number of studies across HE (e.g., Olson and Brown, 2018; Miller et al., 2016, 2018; Azmuddin et al., 2020).

Despite their widespread use, Perusall and Nota Bene are not without their shortcomings. According to its creator, Nota Bene, developed by a novice programmer, offers a "very clunky" user experience [1]. Perusall has a similar level of aesthetic feel and usability to Nota Bene. Finally, the closed codebase of Perusall means there is no way to know how data is processed and stored. Overall, these two projects demonstrate the demand for learning-focused SA tools; however, their shortcomings mean there is a need, addressed by my study, to explore useable, alternative SA tools.

In addressing the usability shortcomings of Perusall and Nota Bene, it is possible to repurpose a commercial annotation system for use in the learning setting. Any tool that allows discussions in the margins of a document can support SA. For instance, Clapp et al. (2021), as part of a departmental level SA learning strategy, evaluated several annotation tools (Diigo, Google Docs, Hypothesis, Kami, Nota Bene, and Perusall), choosing the word processing tool Google Docs. The authors noted that Google Docs has high levels of usability and acceptance. A further creative repurpose of a commercial product is O'Dell's (2020) use of the annotation tool Genius. Genius is a tool to allow music enthusiasts to annotate song lyrics. O'Dell, however, used it to enable literary students to engage in SA

[1] These comments were made by David Karger in a 2019 talk for Microsoft Research (https://youtu.be/LqAhQBDiwd0)

practices. The author remarked that Genius enabled students to annotate using embedded images, videos, and third-party links. Participants also noted that it offered enhanced usability to the education-focused annotation systems discussed above. However, O'Dell concluded that using a commercial annotation system raised privacy concerns stating that they "hope to see a tool akin to Genius that is created specifically with education in mind in the future" (p. 18).

Above, I have established that there is a need for SA tools with the usability of commercial offerings, while at the same time keeping privacy and a learning focus at the centre of the tool's design. Researchers have developed custom SA tools; however, these attempts are for isolated use in specific studies (Zarzour and Sellami, 2017; Shin et al., 2018; Chan and Pow, 2020; Gayoso-Cabada et al., 2019). As such, there remains a need for learning and privacy-focused SA projects made available to the HE community. In creating Arleno, this study addresses this need: I have created a SA inspired tool with high levels of usability, while at the same time keeping privacy and a learning focus at the centre of the design.

3.4.2 Cognitive Presence

This section moves on from the tools used to support SA to consider the levels of cognitive presence it can sustain. Aligned with outcomes of using wider CMC environments, studies have shown a correlation between the use of SA and increased knowledge construction (Benitez et al., 2020; Chen and Su, 2019; Miller et al., 2016, 2018; Gayoso-Cabada et al., 2019). For example, Benitez et al. (2020) split 98 trainee teachers into an experimental and control group. Over the course of a semester, the experimental group used the SA tool Nota Bene to assist their learning. Pre- and post-tests showed a significant knowledge increase accredited to the use of Nota Bene. Chen and Su (2019) found similar results through the pre- and post-testing of 109 Taiwanese information technology students using the SA tool BookRoll. The sample using BookRoll outperformed those who had no access to the system. These outcomes show that SA may support knowledge construction. However, it must be noted that simple pre- and post-test instruments looking at learning through a narrow and simplistic lens were used.

Miller et al. (2016, 2018) address the shortcomings of using simplistic pre- and post-test measurements by incorporating students' exam performances into their study designs. In their 2018 study, Miller et al. evaluated the effect of Harvard undergraduate physics students use of the SA system Perusall. One hundred and fifty-three students, over two semesters, were split between an experimental group using the SA system and a control group with no access. Students across these groups had similar historic exam performance; however, the group using Perusall, over the course of two semesters, outperformed the control group on all but two out of ten in class exams. Further to this, in an earlier study, Miller et al. (2016) showed a positive correlation between engagement in SA activities and exam performance. Interestingly, even when accounting for historic exam performance, students who engage more with SA activities achieve higher relative grade increases than those that do not. Overall, these studies present a clear argument that SA has the potential to increase assessed knowledge and provided motivation to tentatively peruse SA as a solution to address my study's objectives.

3.4.3 Wider Impacts on the Learning Journey

Above, I established that SA use can increase assessed knowledge. However, looking at exam or pre- and post-test scores in isolation gives little insight on how SA enhances the learning journey. As such, this section explores the impact of SA on the wider learning journey. In doing so, I establish that the addition of SA into the learning setting can enhance students' and teachers' voices (Clapp et al., 2021; Kalir et al., 2020), increase motivation (Vorobel et al., 2018; Miller et al., 2016; Zarzour and Sellami, 2017; Chen and Su, 2019), and assist reading comprehension (Kalir et al., 2020; Azmuddin et al., 2020; Yeh et al., 2017).

An interesting observation has been that SA can enhance the students' and teachers' voices; as such, supporting high levels of social presence (Kalir et al., 2020; Clapp et al., 2021). SA provides a means for students, who otherwise would not have the confidence, to raise ideas and communicate with their peers. For instance, Kalir et al. (2020) surveyed 59 Canadian social science students who had used the SA tool Hypothesis to support their studies. Over two thirds (74%) of the

students believed that SA helped them share "knowledge and experiences" with their peers. Clapp et al. (2021) made similar observations after conducting several focus groups with students and teachers. Students indicated that SA allowed them to hear and appreciate the voice of learners who may, in a normal setting, remain silent. Interestingly, Clapp et al.'s discussions with staff revealed this enhanced voice spanned to teachers, allowing them to communicate important pieces of course content more effectively through annotation. As such, SA can enhance both the student and teacher voice. This goes some way towards suggesting that SA is an effective means to support Garrison et al.'s (1999) of social presence in an online learning setting.

If we consider a motivated student one who is more likely to engage in, or show intention to engage in, course content, there is evidence to suggest that SA can increase student motivation (Vorobel et al., 2018; Miller et al., 2016; Zarzour and Sellami, 2017; Chen and Su, 2019). For example, Chen and Su (2019) evaluated the use of the SA tool BookRoll by Taiwanese students. A pre- and post-test survey demonstrated that students participating in the annotation activities showed greater self-reported improvements in self-efficacy and the ability to self-regulate learning. Corroborating these results with a qualitative voice is a small study, conducted by Vorobel et al. (2018), that interviewed five students regarding their experiences of SA. Each student stated that SA motivated them to read and engage more in course content. These studies present a tentative idea that SA can support motivation and at least start the process of behaviourally engaging with text-based materials. However, it is hard to generalise, due to the studies either having small sample sizes (Vorobel et al., 2018); basing their findings off a self-reported survey (Chen and Su, 2019); or in the case of Miller et al. (2018), look at motivation as a secondary objective.

Studies show that SA may help students comprehend reading materials (Kalir et al., 2020; Azmuddin et al., 2020; Yeh et al., 2017). Azmuddin et al. (2020) investigated the use of the SA tool iRead in supporting 55 out of a group of 614 Malaysian science students. Pre- and post-reading comprehension tests showed that SA is effective in increasing reading comprehension in students relative to those who have no access to these activities. It appears, however, that students

may not always agree with these quantitative results. For instance, Kalir et al. (2020) surveyed 59 social science students on their experiences of using the SA tool Hypothesis. They found that only one-third of students perceived SA to help them comprehend reading material. As such, while these studies show that SA presents promise in terms of contributing towards reading comprehension, this conclusion is not definitive.

An overarching theme of the above studies is they largely use self-reported surveys (Chen and Su, 2019; Kalir et al., 2020) or pre- and post-tests (Azmuddin et al., 2020) to report on the learning journey. While the outcomes suggested that SA was well aligned to my study's objective, there is a clear lack of in-depth qualitative inquiry surrounding learners' experiences of engaging with SA activities. While Clapp et al. (2021) and Vorobel et al. (2018) addressed this underserved area through use focus groups and interviews, these are small, isolated attempts. As such, my study's use of semi-structured interviews as the primary data collection technique addressed the need to conduct deeper qualitative inquiry surrounding the subjective experiences of using SA in the learning setting.

3.4.4 SA Teaching Presence

What follows is a consideration of how the design of SA activities in HE informed the choices of the group inquiry-based SA activities developed for my study.

The literature revealed that before developing SA learning activities, the time and space boundaries of the learning setting need to be considered. Clapp et al. (2021) identified that SA activities could be used to complement two distinct learning settings: synchronous (students discuss and annotate in a live session) and asynchronous (students discuss and annotate in their own time). These settings appear to impact the ways students perceive SA. Vorobel et al. (2018) observed that students conducting asynchronous SA activities felt under less pressure. However, when using SA synchronously, they appreciated the instant interaction with their peers.

When deciding between asynchronous or synchronous activities, the study level of the learners becomes the key factor. For instance, Clapp et al. (2021) noted that undergraduate students would contribute to synchronous activities;

however, few would participate asynchronously. They stated, "in most cases, formal assessment is required to produce a substantial asynchronous commentary" (p. 302). Miller et al. (2018, 2016) are also advocates of linking SA activities to grades. For instance, in their 2018 study, students were required to read and asynchronously annotate 17 book chapters. To receive full credit, students had to make seven timely and thoughtful annotations per chapter. Overall, it appears to support undergraduates in SA activities motivators in the form of grades or synchronous activities are required. With this in mind, given that the intervention for my study focused on undergraduate students, I made the decision to design the SA activities to be synchronous. In doing so, I avoided the need to use the extrinsic motivator of assigning grades in return for interaction in the SA community.

After determining the delivery model, activities can be designed around free-flowing annotations; or, more commonly, by teachers seeding the annotation environment with prompts. Through the use of annotation, prompts are situated within the text-based content. For instance, O'Dell (2020) annotated readings with specific questions for students to answer. Miller et al. (2016) explored the effect of "seeding" the discussions; they created fictitious user-profiles and posted high-quality annotations from the previous course cohort, discovering that seeded annotations led to longer discussion threads. As such, discussion prompts seem to be an effective mechanism for triggering Garrison et al.'s (1999) practical inquiry process and underpinned the group inquiry-based SA activities developed for my study. In doing so, I triggered each group inquiry-based SA activity by annotating a section of text-based learning material with an inquiry-focused question.

After triggering an SA activity, the challenge is how to guide students towards the desired learning outcomes. An approach shown to be successful is using structured SA activities (Vorobel et al., 2018; Li et al., 2015; Gayoso-Cabada et al., 2019; Kersh and Skalak, 2018). A structured approach involves scaffolding the annotation process. For instance, Yeh et al. (2017) integrated a technique known as reciprocal teaching; this involved students using Google Docs to annotate text-based learning materials in four specific ways: predicting (confirming or rejecting arguments in the text), clarifying (defining vague or complex terms), questioning (construct questions for better comprehension) and summarising

(synthesising a summary of the text). A further strategy, illustrated by Kersh and Skalak (2018), is recursive reading. This is where students re-read the text multiple times making new annotations each time. The authors noted that by using this approach students were able to see a visual representation of their critical development over the course of the module. Overall, these studies demonstrate how the learning process can be structured using SA.

Based on the insights from the above studies, I developed the group inquiry-based SA activities, supported by Arleno, to be structured and synchronous. I structured the activities around the practical inquiry phases (trigger, exploration, integration, and resolution) necessary to sustain Garrison et al.'s (1999) CoI. An annotation question acted as a trigger. Within an online seminar session, students deliberated an answer to the question in small groups, achieving the exploration phase of practical inquiry. Finally, to support integration and resolution, a nominated member from each group entered the agreed answer into Arleno, sharing it with the wider learning community. Overall, this design supported high levels of cognitive presence.

3.4.5 SA Direct Instruction

Above, I established SA is a welcome addition to the learning setting; however, as with any CMC technique, an instructor must be aware of potential facilitation issues and know when to apply Garrison et al.'s (1999) ideas surrounding direct instruction. What follows is a consideration of issues specific to SA. Further, I establish how these issues led me to refine the learning solution for my study.

From a teacher's perspective, SA activities can be a time-consuming undertaking. Chan and Pow (2020) noted that it may take time for students to become confident in using the tool and adopting it as part of their learning. Teachers must, therefore, be willing to commit time to orientate learners with the new tool. Furthermore, if a synchronous annotation strategy is chosen, teachers can find that annotation-focused activities use much of their instructional time. For instance, Clapp et al. (2021) observed that a simple annotation exercise could take one-hour of class time. Based on these observations, I conducted no more than a single group inquiry-based activity per-seminar session.

From a learner's perspective, SA can be seen as a further demanding task to do. For instance, Kalir et al. (2020) found that students responded neutrally to the idea that SA could improve peer interaction. Students complained that the SA process required a "high degree of self-awareness and even self-policing" (p. 304). Similarly, O'Dell (2020) found that some students complained that SA is a cognitively demanding task to integrate into the complexities of reading academic material. Likewise, Clapp et al. (2021) discovered that students experienced SA to be intensive and demanding. Based on the potentially high cognitive demands of SA, I decided to conduct infrequent deep and meaningful group inquiry-based activities. Further to this, I did not link the outcomes of the activities to grades.

Finally, in terms of tool design affecting activity outcomes, while a SA tool supports more focused discussions than a traditional discussion board, the text-based outcomes may lack depth. Sun and Gao (2016) explored online discussions amongst 45 pre-service teachers. Half the group used a traditional discussion board; the other half used the commercial SA tool Diggo. Sun and Gao found that Diggo produced more specific and focused discussions. However, the discussion board was more conducive to longer, more thoughtful discussions. They concluded this is because Diggo, like most SA tools, only allows a limited amount of space in the margin for discussion. Corroborating this conclusion, an earlier study by Chen and Yen (2013) compared multiple annotation formats. They observed that a pop-up styled box hosting the SA body of text supported greater depth than the standard in-margin discussion. As such, a pop-up area could act as a solution to the lack of depth observed with margin discussions; however, SA tool designers are yet to further explore this approach. My study addressed this need by designing Arleno to incorporate a pop-up area to facilitate the SA activities.

3.5 Conclusion and Literature Gaps Discovered

I began this literature review by searching systematically for empirical studies focusing on CMC and SA's use in the HE setting; in total, 49 studies were retrieved. On categorising these studies, some immediate underserved areas of inquiry were discovered. First, there was an over representation of work focused on an education discipline, accounting for 26.53% of all studies. Second, most

researchers focused on using CMC and SA to complement face-to-face learning, accounting for 75.51% of all studies. As such, by developing a learning solution to support synchronous online learning in a computing discipline, I am investigating a lightly explored delivery model and subject area.

On a more granular level, a clear lack of in-depth qualitative inquiry was discovered. Out of the studies retrieved, only three used focus groups or interviews to gain insights regarding learners' perceptions of SA and CMC environments (Azmuddin et al., 2020; Harris, 2017; Clapp et al., 2021). In deploying interviews as a primary data-collection method, my study makes a significant contribution to this lack of qualitative inquiry.

A final observation, based on categorising studies, most were focused on the overall outcomes of CMC or SA. Only two considered how students interacted with CMC environments or SA tools (Dahl, 2016; Vinagre and Corral Esteban, 2018). In addressing this gap, I have investigated the affordances and process of students using Arleno to support SA.

After categorising the literature, themes were extracted, and three wider study contributions relating to tool and learning design were established. First, most CMC environments are supported through LMS discussion boards. However, students showed a greater acceptance of modern social discussion tools (Gronseth and Hebert, 2019; Harris, 2017). Teachers, though, must proceed with caution as repurposing social discussion tools raises concerns of privacy, data usage and ownership, and depth of discussion (Davis, 2010; Tuhkala and Kärkkäinen, 2018; O'Dell, 2020). To remedy these concerns, O'Dell (2020) called for teachers to work with developers to guide the creation of modern SA tools; however, the call has gone largely unanswered. While there are two notable learning focused SA projects: Nota Bene and Perusall (Zyto et al., 2012; Miller et al., 2018), neither follow a modern design. Furthermore, Perusall is closed source and cannot be extended or inspected by developers. As a developer, teacher, and researcher, I have been able to develop and introduce a modern SA tool into my own teaching setting. Further to this, I have made the tool open-source, meaning it can be freely used in wider HE environments. Second, there is evidence margin annotations are less effective than pop-ups in terms of depth of discussion (Sun and Gao, 2016;

Chen and Yen, 2013). In developing Arleno myself, I have been able to make granular design decisions, experimenting with unexplored features and their potential to enhance educational and social affordances. Finally, very few studies consider digital and learning design concerns. Through following a DBR methodology, I have developed general recommendations pertaining to SA tool design and learning activities.

Chapter 4: Research Design

This chapter explores the research design adopted for the study. I begin by revisiting the study's aim and research questions. I then consider my pragmatic philosophical position that underpinned this research and why the design-based research (DBR) methodology is well suited to this position. Next, I explain how I used DBR to develop, design, and empirically test group inquiry-based activities based on the open-source learning tool Arleno. I close the chapter by considering validity, reliability, generalisability, limitations, and ethical issues. Overall, I present a three-year process that resulted in the empirically tested, open-source learning tool Arleno; a tool that engages students, through scaffolding group inquiry-based SA activities, in text-based learning materials.

4.1 Research Aim and Questions

This study addressed the aim of constructing a solution to engage second-year computing students in taking what Marton and Säljö (1976) call a deep-level approach towards engaging with text-based materials. This approach requires learners to engage critically with text-based content, making connections between the content and wider ideas. In addressing this aim, guided by Garrison et al.'s (1999) CoI framework, I mapped sound socio-constructivist learning theory to the concrete implementation of a new learning tool named Arleno. The tool supported group inquiry-based annotation activities that deeply engaged students in text-based learning materials. Using a DBR methodological approach, I adopted the roles of teacher, programmer, and researcher to refine and test the tool across two twelve-week interventions in my practice setting. Overall, this process allowed me to address the following research questions:

1. How was the design and development of the open-source learning tool,

Arleno, managed?

2. To what extent did the outcomes of the group inquiry-based SA activities, facilitated by Arleno, support cognitive presence?

3. How did the educational affordances of Arleno's design support teaching presence in terms of the design, facilitation, and direct instruction of the group inquiry-based SA activities?

4. What were students' historic perceptions towards text-based learning materials and group work; and, in terms of text-based learning materials, how did the interventions change these perceptions?

5. What were students' perceptions and experiences of using Arleno in terms of the group inquiry-based SA process followed, the social presence supported, and the usability?

4.2 Philosophical Position

As established above, this study addressed the aim of engaging students in text-based learning materials by designing, implementing, and empirically testing a new learning tool. The outcome is change orientated and captures my desire to understand and act. In other words, the quest for knowledge by itself does not address my practical, solution orientated belief; rather, I look to understand and solve problems. In doing so, I adopt a flexible approach towards choosing methods, techniques, and procedures. In taking this approach, I situate my philosophical position as a pragmatist.

Pragmatism is often referred to as a "what works" approach to research. However, according to Morgan (2014), this is an oversimplification. Instead, Morgan argues that pragmatism is an emerging research paradigm. For Morgan, a paradigm is a shared set of beliefs amongst a community of researchers. These beliefs, in turn, influence the research questions asked and the methods used to answer them. Pragmatism represents a shift from the traditional paradigms (e.g., positivism, constructivism, and interpretivism) that rely on ontological and epistemological beliefs to inform the nature of reality and what can be studied.

Pragmatists, rather than grounding their research in the metaphysical, start with a research question and apply the most suitable methods to answer it (Cohen et al., 2011). Depending on the context and application of these methods, reality can be both objective and socially constructed. As such, multiple and mixed-methods are often used. Overall, pragmatism is both methodologically and metaphysically flexible.

Dewey's early work on pragmatism best captures my philosophical alignment to research. For Dewey, research should facilitate the "settlement of some issue [...] and not, as in scientific inquiry, for its own sake" (p. 60). In referring to the "settlement of some issue", Dewey takes a human-centred approach. This is evident in their belief that humans navigate the world through a series of interactions. Most of these interactions are routine and involve little conscious effort to achieve the desired outcome, known as a "determinate situation". Conversely, when these interactions cause conflict, undesirable, or unexpected outcomes this leads to an "indeterminate situation". Such a situation "is inherently doubtful" (p. 105). Pragmatic inquiry involves developing a solution to transform an indeterminate situation into one that is determinate. In other words, the inquiry removes doubt from a situation. This definition can be used to frame my research which focused on solving the indeterminate situation of students not engaging in text-based learning materials.

4.3 Methodology

Above, I established my research philosophy is aligned to the pragmatic process of identifying, understanding, and solving problems in the learning setting. Aligned to this idea, I chose the solution-orientated, interventionist approach of DBR to guide this study. DBR emerged from the design experiments of Brown (1992) and Collins (1992). The experiments challenged the dominant lab-based, positivistic research used to inform learning design at the time. Brown and Collins observed that outcomes from this style of research, based on natural science research design, could not be replicated in real learning settings. In response, design experiments turn to design science, as opposed to natural science, as guidance. The experiments rely on design engineering principles to simultaneously implement and

test pedagogical innovations. Experiments are normally iterated, allowing for the refinement of innovations. Overall, the design experiment approach was aligned with my goal of designing, developing, and testing a learning solution addressing the problem of students taking a surface-level approach towards text-based learning materials.

Since the design experiments of Brown (1992) and Collins (1992), several variants of DBR have emerged (e.g., McKenney and Reeves, 2012; Design-Based Research Collective, 2003). Specifically, I chose McKenney and Reeves' (2012) "Generic Model for Design Research" (GMDR). According to McKenney and Reeves, the GMDR is "theoretically oriented, interventionist, collaborative, responsively grounded, and iterative" (p. 76). As such, adhering to the fundamental characteristics of DBR. In expanding on these characteristics, ideas from curriculum and instructional design are incorporated into the model. The model is operationalised through three sequential phases of action referred to as micro-cycles. The micro-cycles are "analysis and exploration", "design and construction", and "evaluation and reflection". Each micro-cycle demands distinct activities to occur:

- **Analysis and exploration:** further define the problem space and establish existing attempts to solve similar problems.
- **Design and construction:** a solution is constructed with the view of solving the problem identified in the earlier phase, if this is a repeat phase, then the solution is refined.
- **Evaluation and reflection:** requires testing the solution in the learning setting and gathering data to evaluate its effectiveness.

Once completed, the above phases constitute what Mckenney and Reeves refer to as a "meso-cycle". Repeating the meso-cycles allows for the refinement of the solution. Overall, the iterations of meso-cycles form what is known as a macro-cycle. Therefore, the macro-cycle captures the entirety of the research process.

The goal of the macro-cycle is to engineer a solution to the identified problem. Further, it should provide theoretical contributions assisting with the

understanding of the problem, the process followed, and the resulting solution. Finally, it should facilitate the development of design principles. Design principles are empirically-grounded, prescriptive recommendations regarding the solution and design process. Overall, this ensures that the research has utility outside the intervention setting.

4.3.1 Why Not Action Research?

Above, I have introduced DBR as my methodology for this study. However, besides two weeks, I assumed the position of researcher-teacher delivering the interventions. Consequentially, I also considered the teacher-researcher methodology of action research (AR). DBR and AR appear strikingly similar, with researchers struggling to differentiate between the two (Anderson and Shattuck, 2012). Both bridge the gap between theory and practice by attempting to pragmatically effect change in learning settings. Further, both advocate iterating through multiple naturalistic interventions (Bakker and Eerde, 2015; Cohen et al., 2011; McKenney and Reeves, 2012). However, subtle differences between the two approaches made DBR a more appropriate choice.

I decided on DBR for two reasons. First, AR often has a critical focus, adopting an emancipatory stance (Cohen et al., 2011). Conversely, DBR is politically agnostic and design focused. Second, AR is normally used to effect focused localised change. However, DBR must have theoretical and practical contributions spanning beyond the local setting (Design-Based Research Collective, 2003; McKenney and Reeves, 2012). In other words, DBR is the search for solutions and knowledge that others may apply; whereas AR is a means for a teacher to improve their teaching practice. A DBR solution may be tested in a localised setting; however, there is always a commitment to identify generalisable design principles. While some may argue there are aspects of AR in my research approach, I found the politically agnostic, design focus, and the commitment to generalisable solutions that DBR offered better suited my needs.

4.4 Research Setting

This study facilitated the construction and empirical testing of the open-source learning tool Arleno. The tool allowed for content management and the facilitation of group inquiry-based SA activities embedded within the content. In line with the culture of DBR, the testing took place across two semester-length interventions. The setting was the computing department of a teaching-intensive UK-based university where, for the past six-years, I have worked as a lecturer. The student body can be largely categorised as non-traditional (Taylor and House, 2010). Overall, this presented a challenging culture to achieve the aim of engaging them deeply in text-based resources. However, in achieving this aim, the solution should be easier to apply in more traditional HE settings.

4.5 My Position

In conducting this DBR project, I assumed the roles of programmer, teacher, and researcher. I was responsible for:

- Developing the learning tool Arleno and group inquiry-based SA activities based upon it.
- Assuming the role of teacher to facilitate two 12-week interventions with 50 and 75 participants taking second-year synchronous online modules in database programming and research methods. Across these interventions, nine group inquiry-based SA activities that generated 50 answers were run.
- Evaluating the interventions through content analysis of the 50 answers, 24 semi-structured interviews, and analysing my researcher and programmer field notes.

The DBR project took place in my direct teaching setting where I have worked for six years. I, therefore, operated in the capacity of an insider-researcher (Unluer, 2012). Assuming this position provided three benefits: first, I had in-depth knowledge of the research setting and familiarity with the participants; second, I had easy access to the setting and participants; third, I integrated the

research into my daily practice. These benefits allowed the use of data collection methods related to both the outcomes and process of delivering the interventions.

While my position as an insider researcher allowed me to generate insights from a unique perspective; this position also presented the risk of introducing biases into the research. According to Bonner (2015), an insider researcher risks being overly familiar with the research setting. Further, I spent months developing the learning tool, and it was impossible not to form an emotional attachment. This attachment could have influenced the subjectivity of the evaluation. Avoiding these pitfalls required continually examining my positionality and emotional attachments. In doing so, to the best of my ability, I was able to reflexively bracket my assumptions, biases, and attachments (Finlay, 1998).

My continued reflexive analysis led to the following actions:

- Throughout the interventions, I made a conscious effort to not overly focus on the learning tool when teaching. It simply formed a small part of the overall learning experience.
- Taking a pragmatic approach allowed me to use multiple perspectives to triangulate the findings. Semi-structured interviews and observations provided a learners' and teacher's perspective. A more objective view was gained from quantitative content analysis of the group inquiry-based SA activity outcomes.
- Before conducting interviews, I planned a protocol designed to avoid leading questions.

Taking the above precautions allowed me, to an extent, to set aside assumptions, biases, and attachments. However, the process also made me aware that complete neutrality would not be possible. This worked as an advantage, allowing me to add my voice to the data set. In doing so, I provided valuable insights and recommendations concerning technical and learning design challenges.

Meso-cycle: DBRC1		
Micro-cycles		
Analysis & Exploration Mar (2019) - Jul (2020)	Design & Construction Aug (2020) - Nov (2020)	Evaluation & Reflection Oct (2020) - Dec (2020)
• Literature scoped. • Problem defined. • Theoretical framework established. • 6 teaching practitioners interviewed. • Design guidelines established.	• First version of Arleno developed. • First intervention developed. • Programmer logs maintained.	• First 12-week intervention conducted (50 students). • 4 group inquiry-based SA activities conducted. • Field notes maintained. • 12 participants interviewed.
Meso-cycle: DBRC2		
Micro-cycles		
Analysis & Exploration Dec (2020)	Design & Construction Jan (2021) - Mar (2021)	Evaluation & Reflection Feb (2021) - May (2021)
• Preliminary data analysis conducted. • Literature revisited. • New design guidelines established.	• Second version of Arleno developed. • Second intervention developed. • Programmer logs maintained.	• 12-week intervention conducted (75 students). • 5 group inquiry-based SA activities conducted. • Field notes maintained. • 12 participants interviewed.

Table 4.1: The DBR Macro-cycle followed, adapted from McKenney and Reeves (2012, p. 78).

4.6 Applying DBR

To recap, in conducting this study, I adopted McKenney and Reeves's (2012) "Generic Model for Design Research". Following their guidance, I applied the model by iterating over micro- and meso-cycles to form a single macro-cycle. Table 4.1 contains an overview of the macro-cycle that captures the overarching DBR process. The entire process consisted of a macro-cycle conducted between March 2019 and April 2021. The macro-cycle comprised of two meso-cycles that I refer to as DBRC1 (March 2019 to December 2020) and DBRC2 (December 2020 to May 2021). Each meso-cycle contained three micro-cycles:

- **Analysis and exploration** involved constructing and refining a theoretical framework and design principles to guide the creation of a solution to engage students in text-based learning materials.
- **Design and construction** involved implementing and refining a learning solution and the intervention it would support. It was a process of mapping sound socio-constructivist learning theory, captured by the design principles, to concrete implementation and pedagogical design. The outcomes were the open-source SA tool Arleno (see Figure 4.1; p. 70) and two intervention protocols based upon it.
- **Evaluation and reflection** hosted two 12-week interventions underpinned by the newly created learning tool, Arleno. Across these interventions, nine group inquiry-based SA activities were conducted, generating 50 answers. Further to this, 24 post-intervention interviews with participants were conducted (12 after each intervention).

4.6.1 Conducting a Pre-Study

According to McKenney and Reeves (2012), learning solutions underpinned by a DBR methodology evolve over time. For McKenney and Reeves, DBR does not comprise a single linear line of inquiry; preferably, the overarching study should result from multiple sub-studies. Aligning with this idea, the DBRC1 analysis and exploration meso-cycle included a 2019 stand-alone pre-study, not reported on in this thesis.

I conducted the pre-study as part of the master's element of the PhD that resulted in this thesis. The study consisted of conducting semi-structured interviews with six teaching-focused academics from different departments across my university; the goals of these interviews were twofold. First, to elicit participants' experiences of their students engaging with text-based learning materials. Second, I asked for feedback and suggestions on an early mockup of a proposed solution to the lack of engagement in text-based learning materials. I combined insights from the literature review and the interviews to develop the first version of Arleno used in the DBRC1 intervention.

The Absence of the Learner Voice in the Pre-Study

Regarding the pre-study sampling strategy, an immediate question arises: why did the pre-study focus only on teaching practitioners, omitting the learners' perspectives? Such insights would have been valuable; however, my rationale for not including them was two-fold:

First, one of the commonly cited concerns of DBR is the large, unmanageable amounts of data it generates (McKenney and Reeves, 2012). Therefore, given the scope of the pre-study, I could only pick one population to interview; I chose teachers, rationalising that their collective experiences of the entire learning setting would allow me to gain a deeper understanding of the challenges of engaging students in text-based learning materials. Further, I believed the eventual spread of the solution would flow downward: first, being adopted by teachers who will then introduce it to their learners. Therefore, defining the problem and validating the solution with teachers, who would serve as early adopters, seemed like the first logical step.

Second, I had a limited sample of students to work with, and I feared conducting pre-intervention interviews with the students would bring attention to the fact that their future learning environment was to be the subject of an intervention. In turn, this may impact the ecological validity of the study, as pre-intervention interviews with the students could bring attention to the fact that their future learning environment was to be the subject of an intervention. Therefore, I chose to wait until the post-intervention interviews to establish

learners' perspectives.

4.6.2 Intervention Settings

As established above, the two evaluation and reflection meso-cycles hosted the 12-week interventions, central to the study. For DBRC1, the intervention setting was a practical second-year database programming module taken by 55 computing students, running between October and December 2020. For DRBC2, I chose a second-year theoretical research methods module taken by 75 students (50 of whom participated in the first intervention), running between January and March 2021. These modules have contrasting learning outcomes: database programming is applied, teaching learners to make real-world, data-driven applications; whereas research methods is theoretical, orientating students with the philosophical and empirical grounds of the computer science research process. I had sole responsibility for delivering these modules. Due to COVID-19, they were conducted synchronously, online over Microsoft Teams. The delivery format was the same across both modules. Weekly, students attended a lecture delivered to the entire cohort and a two-hour seminar session as part of a group of 10 to 25 individuals. It was within these seminar sessions that the learning solution, consisting of the group inquiry-based SA activities, was used.

4.6.3 The Use of the Learning Solution in the Interventions

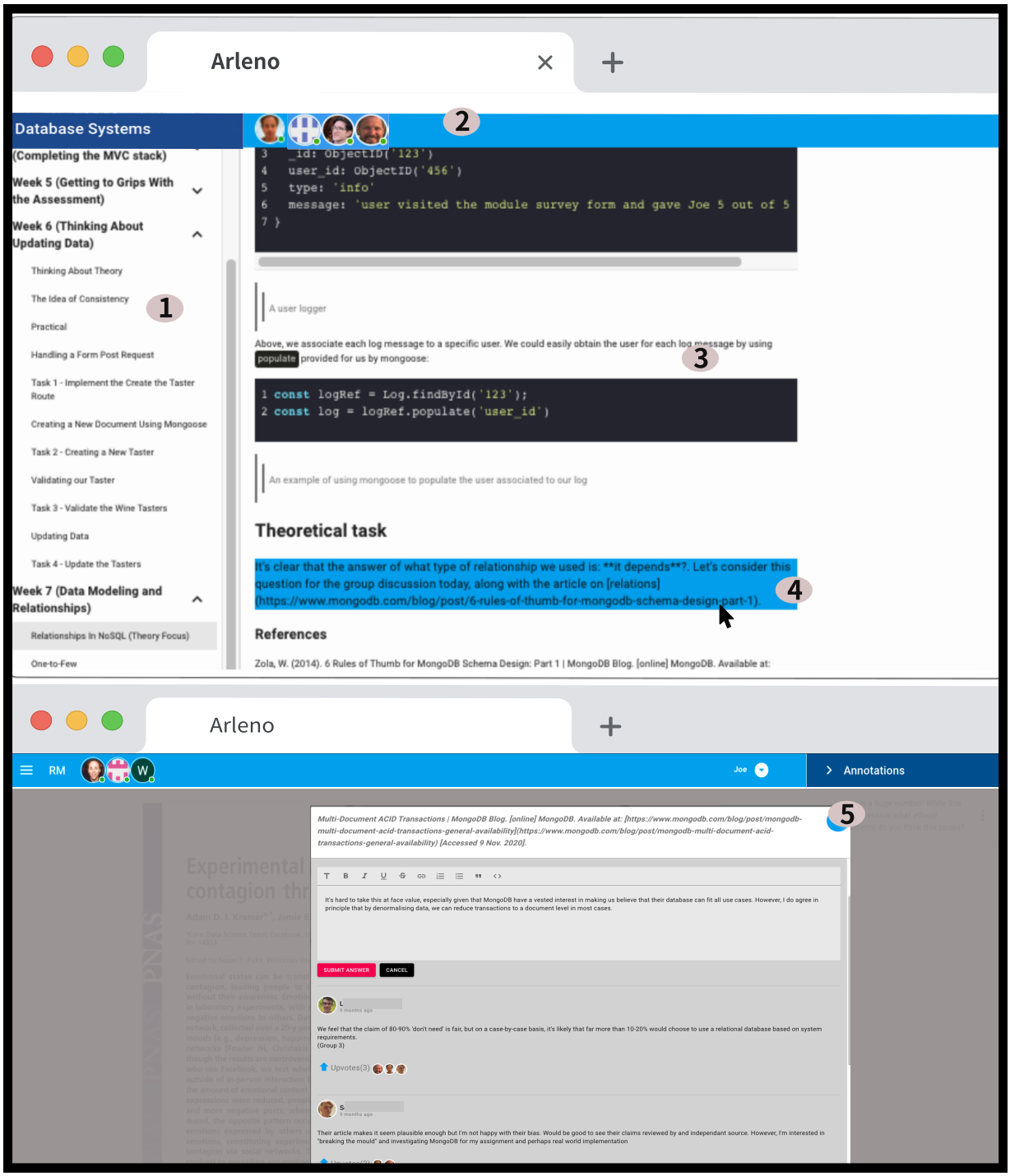

Figure 4.1: *Teacher created content hosted in the first version of Arleno.*
1. Content is created using a simple markdown format and placed in a folder, Arleno then generates a course structure.
2. Viewers of the content are projected onto the screen; I called this feature a presence detector.
3. For readability, code and mathematical notation are highlighted.
4. Annotations attached to course content appear in blue. The blue highlights can be clicked to open the annotation activities.
5. The annotation activity is facilitated in a pop-over.

The learning solution tested, through the interventions, consisted of group inquiry-based SA activities based upon the open-source learning tool Arleno (see Figure 4.1). I developed and refined the learning tool and accompanying activities across the two design and construction meso-cycles. Arleno has two core affordances that facilitated the activities. First, it allows a course creator to organise and present learning materials in an accessible and usable way (see Figure 4.1; feature 1). Enhancing a social connection with the content is the presence detector which projects active readers' profile pictures onto the learning environment (see Figure 4.1; feature 2). Second, it allows a teacher, through annotation, to attach group inquiry-based SA activities to the content. Clicking on the annotated content triggers an overlay to be displayed (see Figure 4.1; feature 5). The overlay contains a teacher-created annotation question, a text area to answer the question, and a real-time stream of answers. Learners can upvote answers allowing each answer to be ordered relative to its total number of votes. Overall, the pop-over serves as a dynamic feed of inquiry activities anchored to the course content.

Week	Concept Explored	Activity	Total Answers
5	Software is created to solve problems.	Groups created a problem statement for the module assessment.	3
6	Data does not have be 100% consistent, 100% of the time.	Groups discussed and summarised the extent they agreed with the concept explored.	5
7	How data is represented and modelled in a database.	Groups listed different scenarios that required data to be modelled in different ways.	6
8	The security performance tradeoff.	Groups determined the completion time of increasing levels of encryption.	7
Total	-	-	21

Table 4.2: A summary of the group inquiry-based SA activities conducted for DBRC1.

Week	Concept Explored	Activity	Total Answers
2	Computing can be framed through a research lens.	Groups used a six-item research framework to propose a computing research project.	6
4	Studies reported on by mainstream media are often based on questionable evidence.	Groups explored a paper widely cited by the press and presented an argument on the generalisability of the results.	5
6	The importance of informed consent.	Groups gave their opinions on a paper that reported on a large-scale study where informed consent was not gained.	9
7	A paragraph is the key unit of writing composition.	Groups critiqued poorly written paragraphs.	6
8	Good writing is re-written.	Groups constructed an editing check list.	3
Total	-	-	34

Table 4.3: A summary of the group inquiry-based SA activities conducted for DBRC2.

Across the two interventions, nine group inquiry-based SA activities were conducted over nine separate weeks, generating 50 text-based student answers. Tables 4.2 and 4.3 summarise the activities run across DBRC 1 and 2, and the key concepts they explored. I followed a similar pedagogical design across the two interventions. Before running the seminars that facilitated the annotation exercises, I annotated a section of the text-based content with a single SA activity that could best help explore a key concept for the week. Students completed the annotation activities in small groups (four to five individuals). For DBRC1, I randomly assigned the students to a different group for each annotation activity. For DBR2, based on feedback from the first intervention, learners self-selected groups, remaining in them for the entirety of the intervention. Across both interventions, the groups had, within the seminar sessions, between 40-minutes and one hour to engage in discussion surrounding the SA activity's inquiry-focused question. The group discussions took place in online breakout rooms, and a single group member entered the collaboratively constructed answer. The answers appeared in real-time in the annotation overlay and could be upvoted by other

students (see Figure 4.1; feature 5). The scaffolded design of the annotation overlay meant that Arleno guided students in the inquiry process.

4.7 Methods

Method	Collection Schedule	Sample
DBRC1 Intervention		
Practitioner Interviews	Mar (2019)	6 teaching practitioners
Programmer Logs	Aug (2020) - Nov (2020)	40 log entries
Field Notes	Oct (2020) - Dec (2020)	4 reflective accounts of the group inquiry-based SA activities conducted
Quantitative Content Analysis of Group Inquiry-based SA Activity Outcomes	Oct (2020) - Dec (2020)	4 activities, generating 21 answers
Intervention Participant Interviews	Dec (2020)	12 out of 55 intervention participants
DBRC2 Intervention		
Programmer Logs	Jan (2021) - Mar (2021)	49 Log Entries
Field Notes	Feb (2021) - May (2021)	5 reflective accounts of the group inquiry-based SA activities conducted
Quantitative Content Analysis of Group Inquiry-based SA Activity Outcomes	Feb (2021) - May (2021)	5 activities, generating 29 answers
Intervention Participant Interviews	May (2021)	12 out of 75 intervention participants (no participants from DBRC1 were re-interviewed)

Table 4.4: A data collection time frame. Across the two interventions, 75 students participated: 50 in DBRC1 joined by 25 further students for DBRC2.

Method	Sample	RQ	Micro-cycle collected
Semi-structured interviews	24 participants (12 after each intervention)	4 and 5	Evaluation and Reflection
Quantitative content analysis of group the inquiry-based SA activity outcomes	9 activities, generating 50 answers (*mean* answer length = 105 words)	2	Evaluation and Reflection
Field notes	9 reflective accounts after each group inquiry-based SA activity	3	Evaluation and Reflection
Programming logs	89 log entries	1	Design and Construction

Table 4.5: Data collection methods and the research question(s) they addressed.

This section explores the data collection methods deployed across the DBR macro-cycle. Aligned with the tradition of DBR, most of the data were collected in the evaluation and reflection micro-cycles (Reeves, 2006). However, to better understand the process of a teacher assuming the roles of a developer and researcher, I also chose to collect data in the form of a programmer log across the design and construction micro-cycles. Tables 4.5 and 4.4 present the data collection methods used, the research questions they addressed, the micro-cycle they applied to, and the data collection schedule. Methods included semi-structured interviews, quantitative content analysis of the outcomes of the group inquiry-based SA activities, field notes, and programming logs. The semi-structured interviews formed the primary data collection method, 12 after each intervention. The interviews were used to explore the backgrounds, experiences, and changing perspectives participants held towards group work, text-based learning materials, and the use of Arleno to participate in group inquiry-based SA activities. To triangulate the outcomes of the interviews, I used quantitative content analysis and data related to my own experiences (developer logs and field notes); I analysed these data sources at the same time. As such, my approach can be best described as a qualitatively focused simultaneous mixed-methods design (Morse and Niehaus, 2016). Such an approach uses quantitative data to increase the reliability

and understanding of a largely qualitatively orientated study.

Above, I established that the participants' voices represented the primary data source. However, I also took the opportunity to gather data related to my own experiences in the form of programmer logs and field notes. Using this data, I intertwined the results with a design narrative surrounding the construction and use of Arleno (see chapter 5). These perspectives are valuable for two reasons. First, in conducting the research, I assumed the roles of programmer, researcher, and teacher. Rarely are these roles brought together, and my perspective adds value to individuals or teams looking to innovate new learning solutions. Second, Arleno is an open-source tool that is free to use in wider learning settings. As such, my insights on the use of the tool helps the spread of the solution. Overall, in using data sources to construct personal narratives, I could address questions related to the creative process and use of Arleno.

4.7.1 Semi-structured Interviews

Course	No Participants	Mean Age
BSc (Hons) Computer Systems and Networks Engineering	1	23
BSc (Hons) Computing	3	23
BSc (Hons) Cyber Security	4	21
BSc (Hons) Digital and Technology Solutions	6	24
BSc (Hons) Digital Design and Web Development	3	25
BSc (Hons) Software Engineering	7	22
Total	24	23

Table 4.6: Interview participants overview grouped by course.

In considering the specifics of the semi-structured interviews, I interviewed 24 out of 75 intervention participants. I implemented a purposive, non-random sampling strategy Cohen et al. (2011). In doing so, I aimed to select participants that represented the wider population. Participants in the interventions were second-year students taking one of eight computing-related courses. I ensured that there was at least one representative from each course (see Table 4.6 for an overview of participants, and appendix B for a breakdown of each participant). The population consisted of standard age undergraduates, and the mean age for the sample is 23, typical of a second-year HE student. Overall, the sample

represented a homogenous group of similar age individuals undertaking like university courses.

Given my insider position as a teacher delivering the interventions, I had unrestricted access to the population. Therefore, arranging the interviews proved straightforward. After identifying participants, I sent out targeted invite emails containing a participant information sheet detailing the research (see appendix A and C, for a copy of the emails and ethical documents). I emailed accepting participants a link to an online informed consent form. Finally, I arranged a mutually convenient interview time.

I conducted all 24 interviews remotely via Microsoft Teams. Using functionality within Microsoft Teams, I recorded the audio and video of each interview and generated a rough transcript. Interviews lasted between 30 and 75 minutes, with a mean length of 43 minutes. Before conducting each interview, I revisited the participant information sheet and informed consent form, allowing the participants to raise questions. Ensuring the interviewees were comfortable, I clarified they could withdraw from the research within a three-month time frame, and there was no pressure to answer questions.

The interviews were semi-structured; as such, an interview protocol was developed and followed across each interview session:

Set Up

- Explain the purpose of the interview and revisit informed consent.
- Show screenshots of Arleno to re-orientate interviewees with the learning tool and the group inquiry-based SA activities.

Questions

- Exploring participants' background experiences of group work and engagement with text-based resources:
  - In what ways do you feel other students can offer value?
  - How do you feel regarding group work in an academic setting?
    - In what ways do you think it can serve you?

  - In your wider experiences at university have you engaged in academic reading or text-based course content?
    - And how did you find that?

- Exploring the features of Arleno and the process it supported:
  - Can you please tell me the overall process that your group followed when completing the activities?
  - In what ways did engaging in group inquiry-based activities make you think more critically about the learning material?
  - What features did you find useful and why?
  - What features did you not find useful and why?
  - What recommendations do you have for future iterations of the tool?

I designed the above protocol to serve three purposes. First, to further understand the problem surrounding students not engaging in text-based learning materials. Second, my philosophical belief is centred around the best types of learning, and the solution to the problem being tackled, is group-based. As such, I looked to understand students' ingrained ideas surrounding group work. Third, to understand the perceptions surrounding the learning solution deployed as part of the interventions. As the interviews were semi-structured, I did not strictly follow the protocol. As such, if interesting perceptions emerged, I would allow these to develop.

4.7.2 Group Inquiry-Based SA Activity answers

Complimenting the interviews were the answers to the group-inquiry based SA activities. As I had complete control over the SA environment, the activity answers were easy to extract by running a simple database query. Nine inquiry-based activities conducted across the two interventions produced 50 answers, with a mean answer length of 105 words. Overall, this provided a total text corpus of 6,195 words.

4.7.3 Programmer Logs

My programmer logs provided insights into developing the learning tool. I produced logs as part of a development practice known as version control. Version control involves using a tool that takes snapshots of a programming project at key points in development. Should mistakes be made, it is possible to roll the project back to an earlier snapshot. Each snapshot has an accompanying programmer created log message written in plain English. For instance, a snapshot made on the 10th of October 2020 read, "Presence detector is now complete; overall, this was a fairly straightforward feature to implement with no significant delays". Across the project, I created 89 snapshots, and the accompanying log messages provided a time-stamped narrative of the development process.

4.7.4 Field notes

To provide a teacher-focused perspective, I maintained field notes across both interventions. This data source was secondary and used to intertwine the results with a design narrative. Therefore, I took a liberal, unstructured approach towards gathering field notes. They comprised of nine reflective accounts, one created for each group inquiry-based SA activity conducted. To construct the field notes, I used the time-stamped memo functionality of the qualitative analysis tool NVivo. Overall, this process aided reflection and refinement of the SA activities while also providing a data set to construct a design narrative.

4.8 Data Analysis

Within this section, I consider how the data gathered was analysed. The process of developing a new learning tool, conducting two 12-week interventions, and 24 semi-structured interviews generated a large dataset. In collecting this data, I assumed the roles of researcher, programmer, and teacher. Therefore, I could provide a unique perspective on both the process and outcomes of a substantial DBR project. However, given the size of the data set, I knew I would not have time to conduct systematic data analysis on all sources. Eventually, I realised that my perspectives of the DBR process could not be void of bias; however, given that

I used them to intertwine the results with a design narrative and not as the primary data source, they did not need to be. Therefore, I designed a data analysis plan that combined rigorous content and thematic analysis complemented by taking a liberal approach to organising sources related to my perspectives. This allowed me to offer a perspective on using DBR to develop a new learning solution and, at the same time, ensure a rigorous, scientific approach towards testing the outcomes of the development process. In the rest of this section, I sketch out the analytical steps taken to intertwine my perspectives with more systematic approaches to data analysis.

4.8.1 Thematic Analysis of Interview Data

The data generated from the 24 semi-structured interviews formed the primary data source. As discussed above, I conducted the interviews remotely over Microsoft Teams. The analytical process began by precisely transcribing the interviews. To assist in the transcription process, I used the auto-generated transcripts created by Microsoft Teams as a starting point. Next, I watched the video recording of each interview several times, updating the transcripts to represent precisely the conversation. In places, I annotated the transcriptions with non-verbal communication that had meaning. Finally, I imported the completed transcriptions into NVivo, a tool to facilitate the proceeding data analysis.

In terms of choosing an analytical technique for the interview transcripts, I wanted to reveal the participants' voices and, as much as possible, bracket my perceptions. Therefore, I looked to follow an inductive, theoretically-agnostic technique. Further, because of the large amounts of data I was working with, I required a simple, yet rigorous, method. I found Braun and Clarke's (2012) thematic analysis procedure well aligned to these goals.

Braun and Clarke are widely credited with popularising the use of thematic analysis in psychology. Since their 2006 paper, the approach presented has spread widely across social fields of research. The process required analysing the interview transcripts across six stages of action:

1. *Familiarisation.* I read the transcripts several more times. I used NVivo's annotation functionality to attach notes to sections of the conversation that

were interesting or could serve as future codes.

2. *Initial code generation.* Using NVivo's coding functionality, I performed line by line coding, treating each sentence as the unit of analysis. I attached a description to each code; before creating new codes, I reviewed the descriptions to see if an existing code matched.

3. *Grouping codes into themes.* I reviewed the codes and grouped them into themes. This process resulted in 29 codes grouped across eight themes. At this stage what Braun and Clarke refer to as candidate themes were produced.

4. *Reviewing themes.* This step involved reviewing the candidate themes through a two-step process. First, I reviewed the text extracts related to each theme. I ensured these extracts followed a clear and related pattern. Second, I created a thematic map (see Figure 5.5; p. 110) allowing me to review the thematic picture in its entirety, and I ensured each theme was valid when considered as part of a thematic map.

5. *Naming the themes.* This step involved determining theme names; I created names that told a story of the codes that made up the theme.

6. *Reporting the themes.* Finally, I organised the themes to answer the participant focused research questions. I initially planned to present the interview themes in two separate chapters, one for each of the two post-intervention sets of interviews. However, after conducting the preliminary coding of both interview data sets, it became apparent that the codes were similar. Therefore, I combined the codes into themes spanning both interventions, reporting on them in a single chapter. I have presented the outcomes of this process in the results chapter (see Findings 2).

The above process was not linear and involved iterating back and forth between stages. However, this design proved helpful when applied to a DBR project. I conducted the interviews across two evaluation and reflection micro-cycles in December 2020 and May 2021, after each of the two interventions. Using the above approach, I performed preliminary data analysis, up to step three,

after the first set of interviews. I could then base the updated design principles for the second intervention on the participants' perceptions and experiences of the first.

4.8.2 Quantitative Content Analysis

Phase	Indicator	Example
Trigger	Asking a question	Always the teacher created question embedded into the annotation.
Exploration	Information exchange Brainstorming Leaps to conclusions	"I will be creating an application for splitting the bill at restaurants/ deliveries?"
Integration	Connecting ideas Building on, adding to ideas Suggesting solutions	"We feel that the claim of 80-90% 'don't need' is fair, but on a case-by-case basis, it's likely that far more than 10-20% would choose to use a relational database based on system requirements."
Resolution	Testing solutions Applying solutions Real-world application	"In the Strategic Procurement department, at [council x], there is no central database for logging and tracking the formal processes of the procurement projects we're carrying out. Currently, there is a spreadsheet (...) The solution will be tested through the amount of time it saves compared to the existing process

Table 4.7: Practical inquiry phases, indicators, and coding examples (adapted from Garrison et al. (2001)).

I performed quantitative content analysis on the 50 group inquiry-based answers to determine the levels of cognitive presence supported. To recap, cognitive presence is the degree to which learners critically construct meaning through "sustained reflection and discourse" (Garrison et al., 2001, p. 5). Garrison et al. operationalise cognitive presence through their model of practical inquiry (PI). The model identifies four levels of inquiry: trigger, exploration, integration, and resolution. By categorising each answer according to their stage of PI, it was possible to estimate the levels of cognitive presence sustained by the group inquiry-based SA answers.

To assist with determining levels of practical inquiry in text-based discussion Garrison et al. (2001) provides indicators to aid with categorising units

of text into stages of PI. To apply, I treated each answer as the unit of analysis (see Table 4.7 for examples of categorising the answers). Next, I used Garrison et al.'s indicators to code each answer according to their stage of PI. I performed this procedure three times and compared the codes. Following Garrison et al.'s advice, if answers could be categorised as two levels of PI, I used the lower of the two. For instance, if I could categorise an answer as both integration and resolution, I applied the lower PI level of integration. Finally, I presented the results by calculating the frequency of answers by stages of PI alongside basic descriptive statistics: mean and standard deviation.

4.8.3 Field Notes and Programmer Logs

As established above, the field notes and programmer logs served two purposes. First, I used them to intertwine the results with a narrative of a teacher developing and testing a learning tool in their practice setting. Second, they allowed for triangulation of the primary data analysis. These personal perspective data sources were, by design, intended to be subjective. As such, I took a liberal approach towards data analysis, consisting of three steps:

- On completion of the two interventions, I imported the field notes and programmer logs into NVivo.
- I read through the logs and field notes several times. As I went through this process, I annotated important sections using NVivo's note functionality.
- After orientating myself with the data, I constructed written narratives surrounding the development process and the group inquiry-based SA activities.
- I used edited versions of the narratives to present the design narrative (see Findings 1).

4.9 Validity, Reliability, and Generalisability

This section considers the validity, reliability, and generalisability of my DBR study. Depending on a researcher's philosophical outlook, the meaning of these

terms can vary (Creswell and Clark, 2017; Cohen et al., 2011). For a researcher assuming a quantitative approach, they are synonymous with repeatability, generalisability, and controllability. However, applying these ideas to a DBR project is troublesome. DBR is not concerned with developing generalisable and repeatable learning outcomes across multiple contexts (McKenney et al., 2006). Rather, it shows a commitment to using interventions in the learning setting to test and mature an innovation, develop design principles, and build theory. As such, what follows is a consideration of validity and generalisability from the perspective of the DBR study conducted.

4.9.1 Validity

My research design shows high levels of ecological validity. Ecological validity means the research setting resembles the real-world (McKenney et al., 2006). The two 12-week interventions, central to the data collection process, were conducted in a real-world learning setting that I had worked in for six years. I had what Creswell (2014) refers to as "prolonged" engagement with the research setting. As such, my presence as part of the interventions was not out of the ordinary. Therefore, the intervention settings were directly comparable to an everyday learning environment.

4.9.2 Reliability

According to Cohen et al. (2011), reliability in quantitative research means that the same research instruments applied to similar samples will produce equivalent results. However, Cohen et al. goes on to argue that these measures are not suitable for research, like mine, with a qualitative focus. Therefore, to avoid direct comparison to quantitative ideals, the researcher should use terms like dependability and trustworthiness.

For this study, I took a qualitatively focused mixed-methods approach. I was not trying to achieve repeatability in my methods; however, I wanted dependable results. With this in mind, I included five key dependability measures. First, to determine the extent the interventions supported learning, I adopted the extensively tested PI model (Garrison et al., 1999). Second, I followed an interview

protocol to ensure consistency across each sitting. Third, I followed a systematic approach, prescribed by Braun and Clarke (2012), to generate themes from the interview data. Fourth, I ensured that the video and audio recorded for each interview were high quality. Fifth, I carefully reviewed each transcript referring to the video to ensure accuracy and elaborated the transcripts with non-verbal communication. Overall, these measures meant that my data collection was systematic and analysed using validated analytical instruments.

4.9.3 Generalisability

According to McKenney and Reeves (2012, p. 20), "in educational design research, generalisation concerns being able to transfer theoretical insights and/or practical interventions to other settings". In line with this definition, generalisability in my research comes from the outcomes of the interventions: the open-source learning tool and the design principles. The design principles guide both the process of conducting a DBR study to create a learning solution; and how to use the learning solution, based on Arleno, that resulted from this study. Further to this, from a practical perspective, Arleno is open-source and free to use by programmers, teachers, and learning designers in their learning contexts. The generalisable outcomes of the research should maximise the spread of my solution and guide individuals looking to create their own.

4.10 Limitations

Above, I presented measures that were put in place to ensure the reliability, validity, and generalisability of my research. However, despite these, the study design raised four limitations. First, given the time constraints imposed by my PhD deadline, I could only run two DBR macro-cycles. While two cycles are considered adequate by researchers such as Pool and Laubscher (2016), I cannot ignore that the learning solution matures with the number of intervention cycles. Second, because of the rapid roll-out of online learning, I could not gather quantitative data such as engagement analytics. Such analytics would have been useful in further triangulating the results with objective data sources. Third, my PhD was an individualistic endeavour; however, there were times when I would

have welcomed the input of a second researcher. For instance, an inter-coder reliability protocol could have added validity to the content and interview analysis. Fourth, while I spread the two interventions across contrasting modules, both were with similar students and in my direct practice setting. Ideally, I would have also liked to have supported third-party practitioners to use Arleno to run interventions in their practice settings. Moving forward, I can address these limitations by running further post-PhD DBR cycles.

4.11 Ethical Consideration

Throughout this study, I subscribed to Cohen et al.'s (2011) advice that sound ethical practices need to be considered early and embedded into the research process. I obtained ethical clearance from Lancaster University and my institution where I conducted the interventions. I identified ethical challenges surrounding three primary activities: data ownership and privacy in a researcher-developed tool, running learning interventions, and collecting data to evaluate these interventions. What follows is an account of the procedures I followed to conduct these activities ethically.

In constructing the learning solution, I put in place two primary ethical safeguards surrounding data privacy and usage. First, I was asking students to engage in an unfamiliar learning environment. Therefore, I ensured the learning environment should enhance the students' experiences, and they all had equal access. Second, I was asking participants to register and interact with my learning tool, raising data privacy concerns. To ensure privacy, I followed the Information Commissioner's Office (IOC) General Data Protection Regulation (GDPR). In line with this guidance, data collection was minimal: only students on the course could register, and I did not store their usernames and passwords. I also made students aware on registration that, while their interactions may be analysed as part of my research, they had the right to have any data related to them removed from the system. These processes meant data collection was kept to a minimum and all participants could benefit from the learning tool.

Interviews with 24 intervention participants were the primary data collection method used to evaluate the interventions. As the interviewees' teacher,

I knew I was in a position of power. Therefore, I needed to ensure that participants did not feel pressured to take part or answer any specific questions. Ten days before conducting the interviews, I electronically distributed participant information and informed consent. Participants electronically signed informed consent, and a signed copy was emailed to me and the participant (see appendix C). Next, at the start of the interviews, I revisited the participant information sheet and co-read it with the interviewees. I re-emphasised that there were no right or wrong answers, or indeed pressure to answer at all. Further, I informed them that they had every right to email me, within eight weeks, to withdraw from the research with no further questions asked. To ensure ongoing data privacy, recordings were stored on an encrypted external hard drive that only I had access to. Finally, I removed all revealing participant characteristics when reporting on the research outcomes.

4.12 Conclusion

This chapter has sketched out how I used a DBR methodology to develop, design, and empirically test a learning solution based on a newly developed tool. In doing so, I described how I conducted two 12-week interventions and used interviews with intervention participants to form the primary empirical data set. I outlined how I triangulated the interview data with field notes, programmer logs, and 50 group inquiry-based SA activity answers. I showed how I took a qualitatively focused mixed-methods approach in analysing this data and ensured high levels of ecological validity. I argued how the analysis of this data led to generalisability in the form of design recommendations and an open-source learning tool that has been made freely available to wider learning communities. As with any research design, I identified some limitations; however, the following chapters will show the research design generated deep descriptive narratives surrounding creating a learning solution that successfully supported students in taking a deep-level approach towards engaging with text-based learning materials.

Chapter 5: Findings 1. A Design Narrative of the DBR Macro-Cycle

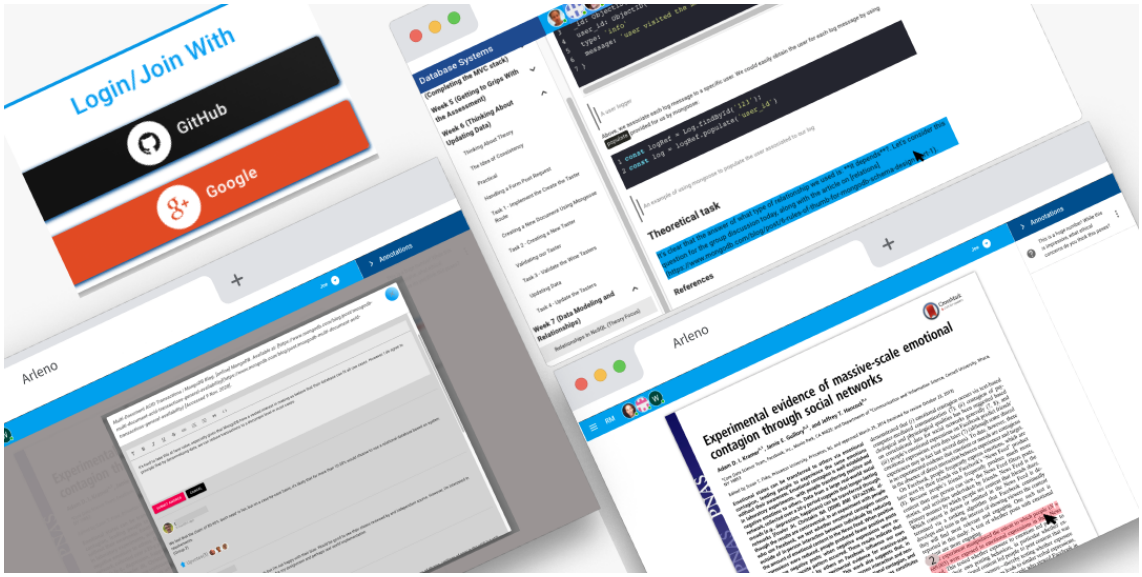

Figure 5.1: An overview of Arleno. An open-source SA tool and content management system, representing the practical outcomes of the DBR study. Over the course of this chapter, I present a design narrative surrounding its design, development, and use.

This chapter, and the proceeding one, present this study's findings. To recap, the overall study comprised of a DBR macro-cycle (McKenney and Reeves, 2012). The practical outcome of the macro-cycle was an open-source, web-based learning tool named Arleno (see Figure 5.1) and group inquiry-based SA activities based upon it. My commitment to open-source means the tool is freely available to the wider software engineering and learning communities. The tool allows for content management and the facilitation of inquiry-based SA activities to be attached to the content. In creating the tool, I assumed the roles of programmer, researcher, and teacher. This allowed me to map sound learning theory to practical implementation. Moreover, it allowed me to test and refine this implementation through two naturalistic interventions in the learning setting

across two meso-cycles referred to as DBRC1 and DBRC2.

In line with McKenney and Reeves's (2012) interpretation of DBR, the meso-cycles consisted of three micro-cycles: analysis and exploration, design and construction, and evaluation and reflection. Data were collected across each of the micro-cycles. However, the majority was generated through the evaluation and reflection micro-cycles that supported two 12-week interventions, evaluating Arleno in the learning setting. These interventions played host to nine group inquiry-based SA activities, supported by Arleno, that were conducted over nine separate weeks and generated 50 text-based answers. This chapter uses the analysis conducted on the programming logs, field notes, and 50 group inquiry-based SA activities answers to present a design narrative describing the two meso-cycles, DBRC1 and DBRC2. In doing so, I answer the research questions:

1. How was the design and development of the open-source learning tool, Arleno, managed?

2. To what extent did the outcomes of the group inquiry-based SA activities, facilitated by Arleno, support cognitive presence?

3. How did the educational affordances of Arleno's design support teaching presence in terms of the design, facilitation, and direct instruction of the group inquiry-based SA activities?

What follows is a design narrative that addresses the above questions. I progress through each micro-cycle that contributed to the overarching DBRC1 and DBRC2 meso-cycles: analysis and exploration, design and construction, and evaluation and reflection. I use the narrative surrounding the analysis and exploration and design and construction cycles to answer research question one. I address research questions two and three through the narrative of the evaluation and reflection cycles, where I map cognitive outcomes to teaching concerns.

5.1 DBRC1: Meso-cycle

This section maps out the DBRC1 meso-cycle, conducted between March 2019 and December 2020. As explained above, I progress through the analysis and

exploration, design and construction, and evaluation and reflection micro-cycles that contributed to the DBRC1 meso-cycle.

5.1.1 Analysis and Exploration

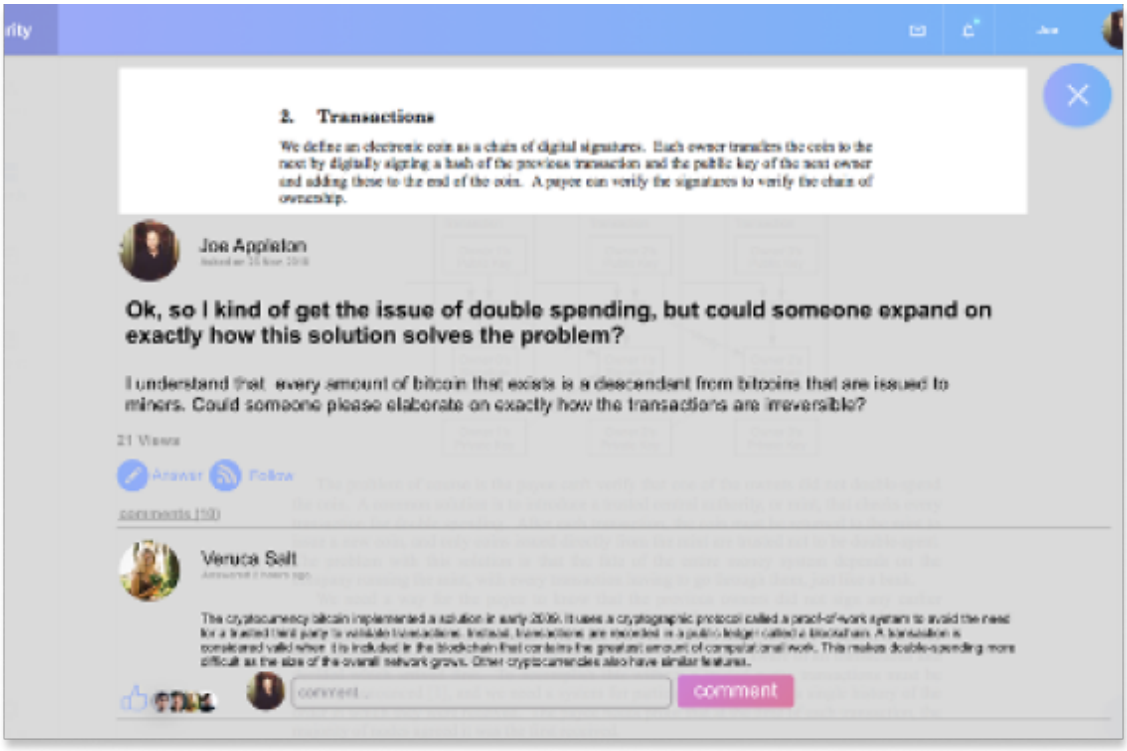

Figure 5.2: An early mock-up of an annotation tool.

The first analysis and exploration cycle, conducted between May 2019 to July 2020, marked the initiation of a DBR project lasting three years. The aim of this phase was "problem identification and diagnosis" (McKenney and Reeves, 2012, p. 79), and because of the scope of the DBR project, it started before the main body of work conducted for this thesis. In 2019, as part of a taught component of the PhD that resulted in this thesis, I conducted semi-structured interviews with six teaching-focused academics from different departments across my university. The goals of these interviews were twofold. First, to elicit the participants' experiences of their students engaging with text-based learning materials. Second, I asked for feedback and suggestions on an early mockup of a proposed solution to the lack of engagement in text-based learning materials (see Figure 5.2). The outcomes revealed that lack of engagement with text-based learning materials was an

institution-wide problem. Further, the outcomes suggested that the mockup presented a possible solution that would work in wider learning settings.

Guided by the outcomes of the interviews, I conducted a literature review aligned with my philosophical belief that the best types of learning are collaborative and discursive (Garrison et al., 2001; Vygotsky, 1980). The combination of the interviews and the literature review allowed me to construct the following design principles:

- The process of accessing and using the system should be aligned with the usability standards set by modern social media applications. This contrasts with commonly used LMS systems where there are often several steps to log in, and content is poorly indexed and hard to discover (Gronseth and Hebert, 2019; Harris, 2017).

- In terms of depth of discussion, there is evidence to suggest that margin annotations are less effective than an annotation area that overlays the content (Sun and Gao, 2016; Chen and Yen, 2013). As such, the SA activities should be facilitated in a pop-over window.

- To support a focused inquiry approach, the tool should only allow the outcomes of the inquiry process to be posted to the SA pop-over; encouraging deep and meaningful answers, as opposed to frequent transactional messages that may lead to low levels of cognitive presence (Garrison et al., 2001).

5.1.2 Design and Construction

The design principles developed in the analysis and exploration micro-cycle supported the design and construction micro-cycle, conducted between August and November 2020. This micro-cycle, as it sounds, was dedicated to constructing the learning solution and was a process of mapping sound socio-constructivist learning theory, captured by the design principles, to concrete implementation and pedagogical design.

The process started by translating the established design principles into user stories. User stories are a common design tool used in software development (Cohn, 2004). Each story consists of a short description of how a specific user

group will interact with a small part of the proposed system. For example, "As a teacher, I should be able to invite students to join the system". The stories were then prioritised through the use of the MoSCoW method (must have, should have, could have, and will not have). This approach allows a programmer to start implementing the most important "must have" features first. Overall, this process allowed me to further empathise with potential future users of the new learning tool and prioritise the order features would be implemented.

In late August 2020, I began programming the user stories in priority order. The goal was to have the learning solution ready for the first semester of the 2020 academic year (October 2020). The user stories presented two technical challenges. First, the system had to be able to index and display teacher created and PDF content. Second, there should be functionality allowing inquiry-based annotations to be attached to this content.

Development progress was steady for the first month. However, come September, because of the ongoing COVID-19 pandemic, my university was transitioning all learning online. This resulted in a significant amount of work, and the development of the tool overran. As such, the first technical challenge of hosting content was solved at the start of the semester; however, the annotation functionality was not completed until the start of November. Further to this, I decided to only allow annotations to be attached to hypertext markup (HTML) content, as opposed to portable document format (PDF) files. HTML consists of a simple structure and is easy to work with. In contrast, a PDF file is a complex document, challenging to interpret, and hard to anchor annotations to. I should also note that, at this stage, some basic programming skills were required to attach the annotations. On concluding the first design and construction meso-cycle, I had developed a modern looking learning tool that I named Arleno (see Figure 5.3). Other than time pressures, the cycle went smoothly; however, the sheer size of the project cannot be underestimated: my development logs reveal that I had accumulated over 500 development hours and wrote 75,000 lines of code.

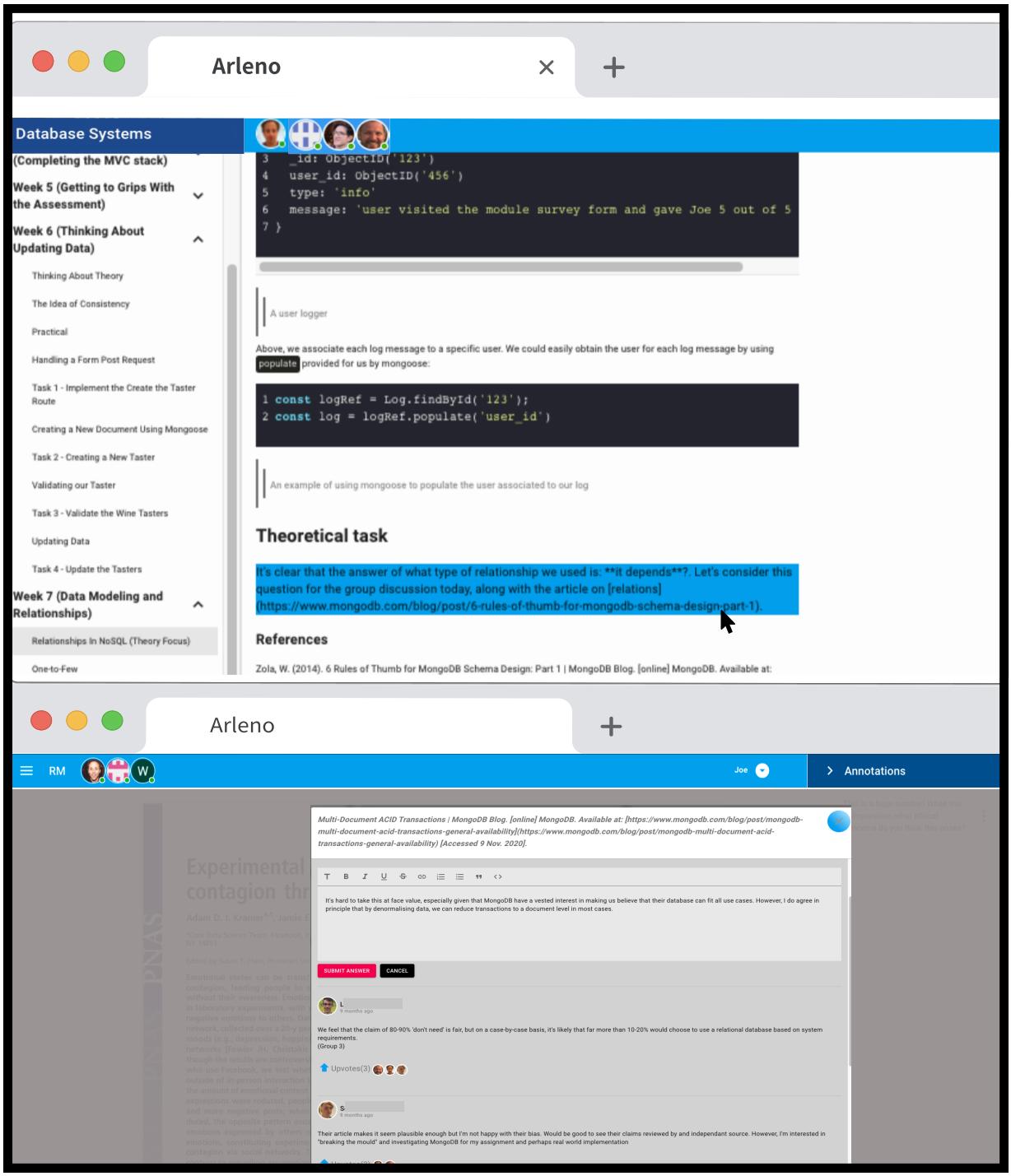

Figure 5.3: The first version Arleno, used for the first intervention

5.1.3 Evaluation and Reflection

The evaluation and reflection micro-cycle, taking place between October and December 2020, hosted the first 12-week intervention. As discussed earlier, the intervention setting was a semester-long second-year database programming module, taken by 50 computing students. The module content and group

inquiry-based SA activities were facilitated by version one of Arleno. The university's LMS hosted administrative concerns such as assessment submission.

Week	Trigger (Weekly Total) (%)	Exploration (Weekly Total) (%)	Integration (Weekly Total) (%)	Resolution (Weekly Total) (%)	Total - (%)
5	1 25%	0 0%	2 50.00%	1 25.00%	4 100%
6	1 16.67%	0 0%	2 33.33%	3 50.00%	6 100%
7	1 14.29%	0 0%	6 85.71%	0 0%	7 100%
8	1 12.50%	0 0%	0 0%	7 0%	 100%
Total	4 16.00%	0 0%	10 40%	11 44%	26 100%
M *SD*	1 0	0 0	2.5 2.52	2.75 3.10	6.25 1.71

Table 5.1: Triggers and Answers for the DBRC1 group inquiry-based activities, categorised according to Garrison et al.'s (2001) stages of practical inquiry.

The first intervention hosted four group inquiry-based SA activities across four weeks, generating 21 answers ($M = 5.25$; $SD = 1.71$). To determine the extent the answers supported cognitive presence, the 21 answers and four triggers were coded in accordance with Garrison et al.'s (2000) practical inquiry model (see Table 5.1). The trigger was always the question embedded into the annotation, accounting for 16% ($n = 4$) of all stages of practical inquiry. A single trigger was used for each SA activity, hence four triggers across the same number of activities. The answers were distributed across the integration ($n = 10$; $M = 2.50$; $SD = 2.50$) and resolution ($n = 11$; $M = 2.75$; $SD = 3.10$) phases of practical inquiry. According to Garrison et al., content categorised as integration and resolution demonstrates a high level of cognitive presence. As such, it can be concluded that the SA activities supported by Arleno resulted in high level of cognitive presence and were the product of a productive Community of Inquiry.

Beyond indicating high levels of cognitive presence, the outcomes of categorising the triggers and answers according to the Garrison et al.'s (2000)

practical inquiry model presented two outcomes of note. First, there were no answers categorised at the lower exploration level of practical inquiry. This may be due to the design of Arleno not allowing for transactional interactions that typify exploration. Furthermore, the practical nature of the module meant that students would often have to connect theoretical ideas to real-world solutions. In doing so, they sustained higher levels of practical inquiry. Second, the week eight activity accounted for seven of the ten answers categorised as resolution (the highest level of practical inquiry). This was due to the activity design requiring students, in answering the SA question, to test and propose solutions. As such, resolution was supported by design; however, this outcome was heavily scaffolded. This observation highlights the importance of providing a narrative to the above quantitative measures. As such, what follows is a narrative account of the annotation activities.

DBRC1: Activity Narrative

Teaching **week 5** marked the first week that students used Arleno to participate in group inquiry-based SA activities. The key concept for the week focused on the idea that software is created to solve real-world problems, not just to pass assessments. As such, the activity was anchored to a section of content that highlighted the importance of articulating the problem their database application would solve for the module assessment. The activity involved students, in their groups, devising a model problem statement and solution.

In total, three groups provided an answer. In terms of the number of answers, the outcomes were disappointing. However, they all reached integration ($n = 2$) and resolution ($n = 1$) levels of practical inquiry. The inquiry indicator "explicit characterization of the message as a solution by the participant" was used to categorise two of the answers as integration (Garrison et al., 2001, p. 19). For instance, group two answered:

> "Mike is having trouble tracking his weightlifting. ... Ideally, Mike would be able to track his workouts, understand trends in the data, forecast future workouts and set goals."

The above answer is tentatively suggesting a solution; however, it is brief with little in the way of underpinning evidence and sits at an integration level of practical inquiry. Group one, however, provided a more developed answer and presented "a vicarious application to real-world" (Garrison et al., 2001, p. 19). As such, reaching the highest resolution level of practical inquiry:

> "Within the Strategic Procurement department, at [council x], there is no central database for logging and tracking the formal processes of the procurement projects we're carrying out. Currently, there is a spreadsheet (...) The solution will be tested through the amount of time it saves compared to the existing process."

Overall, despite the low number of answers, those that did answer achieved a high level of practical inquiry. Furthermore, students had little trouble using Arleno. Once the students were in the breakout rooms, they managed to facilitate the inquiry process themselves. As such, the first SA activity, facilitated by Arleno, represented a positive start.

The SA activity for **week 6** was attached to a section of the course content that presented a divisive argument. The argument exposed students to the key concept that the correctness of data in a database is dependent on the type of data being stored. The argument concludes, 90% of database applications do not require high levels of correctness. The SA activity required groups to explore this idea and construct an argument revealing the extent they agree. Overall, this saw an increase in engagement and number of answers compared to the previous week's SA activity ($N = 5$ vs $N = 3$). The answers were distributed across integration ($n = 2$) and resolution ($n = 3$) levels of practical inquiry. A striking outcome is the majority (n = *3*) of answers were coded as resolution, the highest stage of practical inquiry.

The indicator "building on, adding to others' ideas justified" was used to categorise two of the answers as integration (Garrison et al., 2001, p. 16). For instance, group two answered:

> "We feel that the claim of 80-90% 'don't need' is fair, but on a case-by-case basis, it's likely that far more than 10-20% would choose to use a relational database based on system requirements."

The above answer builds on the argument presented in the annotated content. Further to this, it starts to develop the tentative hypothesis that the need for accuracy is dependent on system requirements. The three groups reaching resolution took their answers further and had started to formulate testable solutions. For instance, group three's answer was:

> "This idea seems plausible enough, but we are not happy with generalisations made. We suggest, that for the module assessment it might be worth testing this idea with real world implementation and seeing if a counter example could be created to disprove the concept that accuracy does not matter."

In this answer, we see that the group is presenting a clear way to test the idea captured in the key concept. As such, they are reaching the resolution levels of practical inquiry. In summary, the high levels of practical inquiry achieved for the week and the increase in answers, may mean that the controversy and division that the inquiry question focused on could sustain high levels of cognitive presence.

Week 7 explored the key concept of how data is modelled and interrelated in databases. The SA activity required students to map theory to practice by answering a question that asked them to apply the theoretical idea of database modelling to real-world examples.

The process resulted in six answers, and all were categorised as integration levels of practical inquiry. A key difference in the activity design, compared to previous weeks, was the type of question meant the answers could be presented in a succinct notation format. While this allowed precise answers, the groups did not expand on the notation, and did not reach resolution levels of inquiry. As such, the practical inquiry indicator, "characterization of message as a solution by participant" was used to categorise the answers as exploration (Garrison et al., 2001, p. 16). For instance, group five's answer was typical:

> "1 to few - each employee might have a few assessments (e.g. 1 per 6 months) 1 to many - each assessment might contain many skills (e.g. few dozen in logical groups) (...) "

The above answer, although succinct, is clearly presenting a solution. However, it does not go on to further test this solution. Overall, the answers did not reach the highest levels of practical inquiry. However, they met the learning outcomes for the week, with the answers presenting interesting real-world examples. This led me to reflect that as teachers we do not always need to strive for the highest levels of practical inquiry.

Week 8 was notable for two reasons. First, it was the final week that a group inquiry-based SA activity would be run for DBRC1; second, the seven activity answers could be categorised as resolution, the highest level of practical inquiry (Garrison et al., 2001). I believe the reason for the high levels of practical inquiry is the activity design. The key concept was surrounding security performance trade-offs, and the activity involved testing different types of encryption algorithms and recording their outcomes. As such, the only way to address the SA activity was through providing an answer that met the "testing solutions" resolution level indicator of practical inquiry (Garrison et al., 2001, p. 16). Further to this, like in week six, students were able to present their answers succinctly. For example, group seven provided the following answer:

> "We have tested 5 solutions, and the results are as follows: MD5: 0.001s BCrypt10: 0.055s (...)"

The above answer simply captures the results of the encryption experiments run. However, testing was required to generalise and formulate an answer. The activity achieved a balance where high levels of inquiry were required; however, the answers were simple to construct. As such, the highest frequency of answers and levels of practical inquiry were observed in this week.

To conclude the evaluation and reflection cycle, I conducted a round of semi-structured interviews with the participants. The outcomes of the interviews added to an overall dataset that also included field notes and programmer logs, and activity answers. This brought the DBRC1 meso-cycle to a close.

5.2 DBRC2: Meso-cycle

5.2.1 Analysis and Exploration

Following the iterative nature of DBR, the DBRC2 meso-cycle progressed through the same micro-cycles as DBRC1. As such, it began with an analysis and exploration micro-cycle, lasting for the month of December 2020, it was significantly shorter than its DBRC1 equivalent. The rationale was that I wanted to extend the functionality of Arleno and planned to allow as much time as possible for the proceeding design and construction micro-cycle. I focused on conducting a preliminary analysis of the data generated from the first intervention.

The interviews revealed that Arleno and the group inquiry-based SA activities were well received. Further to this, the content analysis showed high levels of cognitive presence. As such, the first version of Arleno had shown much in the way of promise. However, it was still an early-stage prototype, requiring programming experience to attach the SA activities to the content. Furthermore, PDF documents could not be annotated, constraining SA activities to teacher-created content. Finally, the interviews revealed that navigating the group dynamic of a randomly assigned group for each SA activity was a time-consuming and daunting process. Addressing these shortcomings formed the focus of the DBRC2 design and construction micro-cycle.

5.2.2 Design and Construction

In progressing the learning solution and addressing the shortcomings identified above, the DBRC2 design and construction micro-cycle, conducted between December 2020 and March 2021, involved updating Arleno so teachers with no programming experience could annotate PDF documents. Furthermore, I made two pedagogical design adjustments to the SA activities. First, I changed the group inquiry process to experiment with self-selected groups, with students remaining in these groups for the entirety of the SA activities conducted. Second, I chose to test the effectiveness of these activities on a research methods module. The module's theoretical focus contrasted with the database programming module that formed the setting for the first intervention.

I began the tool and pedagogical updates in November 2020, intending to have the updated version of Arleno ready for the start of the second semester of the 2020 academic year (February 2021). From a development perspective, the PDF format and allowing non-programmers to attach annotations to this format presented a challenge. The format dates to 1992, and it is designed to allow portability between different devices. Displaying a PDF is simple; however, the challenge is that when a PDF document is displayed in a web browser it is converted into HTML. While the document appears the same to an end-user, the underlying structure can vary considerably. However, I needed to attach annotations to the same section of the document each time, despite the changing underlying structure.

It transpired that attaching an annotation to a changing document has long been recognised as a complex problem (Brush et al., 2001). The solution was to write an algorithm that extracted just the text from a PDF document. Next, when an individual highlights and annotates a section of the document, three sections of text are stored: the text highlighted and the text to the left and right of the highlighted section. When the document is reloaded, it is searched using the three gathered parameters and the annotation can be dynamically attached. This strategy proved robust to the extent that the annotation position could be maintained even if the content of the PDF document was updated. Once this algorithm was implemented, adding the functionality to allow a non-programming skilled individual to annotate a PDF document was straightforward (see Figure 5.4).

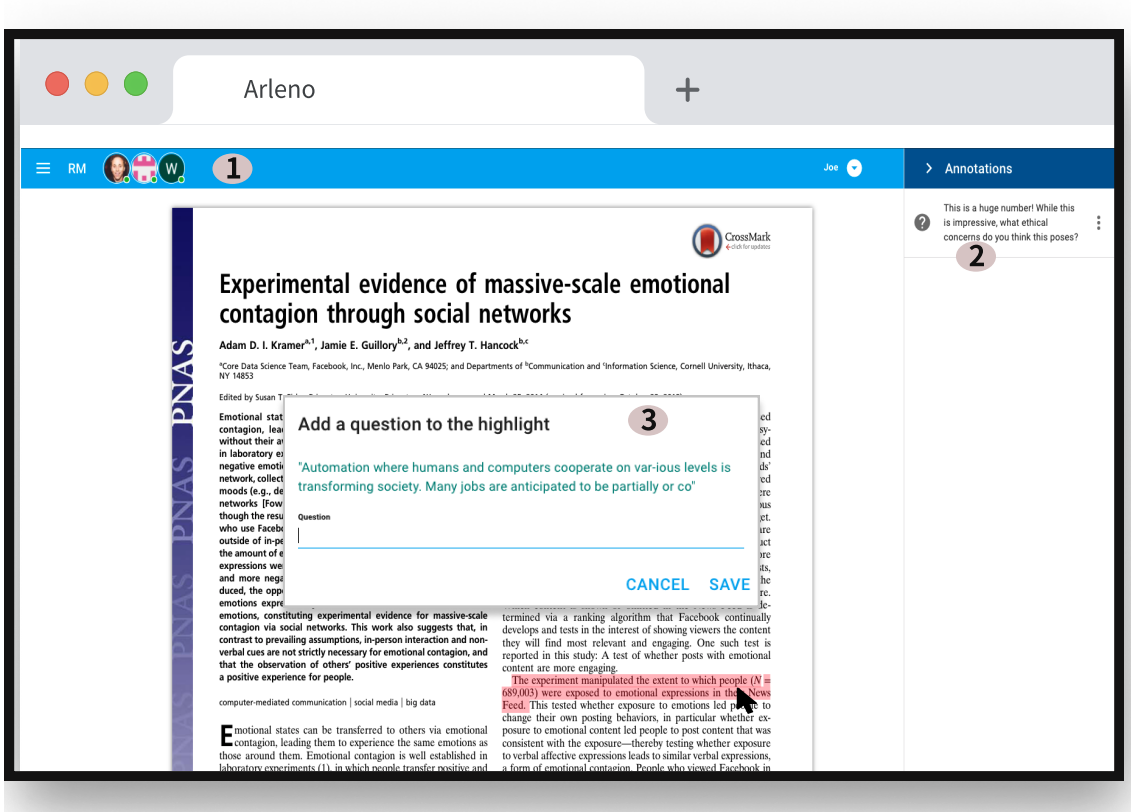

Figure 5.4: *A teacher uploaded PDF document in Arleno.*
1. The presence detector projects the profile pictures of readers above the content.
2. The annotation question is displayed in the sidebar, clicking the question locates the annotation in the PDF document.
3. Teachers create an SA activity by highlighting a section of the PDF document and entering an inquiry-focused question.

Once the technical challenge of anchoring annotations to PDF documents was solved, it became clear that annotations would be hard to locate in longer documents. An individual would have to scan the entire document to locate the annotation highlights. This presented a poor user experience and a further design challenge. The solution was to include a retractable sidebar menu that contained a marker to each annotation. The markers could be clicked, and the browser would then automatically scroll to the annotation location (see Figure 5.4; feature 2). This feature concluded the development cycle of the design and construction phase.

Overall, the development cycle was technically more challenging than DBRC1 and required a considerable amount of time. As such, the PDF annotation feature was not ready until teaching week four of the module. However, as I

already had the functionality to annotate teacher created content, there were no delays in conducting annotation activities for the second intervention. I then incrementally rolled out new features as they were ready.

5.2.3 Evaluation and Reflection

The focus of the second evaluation and reflection micro-cycle was to test the updated tool and pedagogical design of the group inquiry-based activities through an intervention on a theoretical module. As such, the focus of the DBRC2 intervention was a second-year research methods module taken by 75 students, 50 of whom had participated in the first intervention. The module had a theoretical focus, teaching students the computer science research process. The module content, delivered through Arleno, curated third-party philosophical ideas and readings. The SA exercises were altered to allow students to self-form groups in week one of the module. They then remained in the same group for the entirety of the intervention. Other than this, the process surrounding the group inquiry-based SA activities remained the same as the DBRC1 intervention.

Week	Trigger (Weekly Total) (%)	Exploration (Weekly Total) (%)	Integration (Weekly Total) (%)	Resolution (Weekly Total) (%)	Total (Weekly Total) (%)
2	1 14.29%	2 28.57%	4 57.14%	0 0.00%	7 100%
4	1 16.67%	0 0%	5 33.33%	0 50.00%	6 100%
6	1 10.00%	2 20.00%	4 40.00%	3 30.00%	10 100%
7	1 14.29%	0 0%	4 57.14%	2 28.57%	7 100%
8	1 25.00%	0 0%	0 0.00%	3 75.00%	4 100%
Total	5 14.71%	4 11.76%	17 50.00%	8 23.53%	34 100%
M *SD*	1 0	0.80 1.10	3.40 1.95	1.60 1.52	6.80 2.17

Table 5.2: Triggers and Answers for the DBRC2 group inquiry-based SA activities, categorised according to Garrison et al.'s (2001) stages of practical inquiry.

The second intervention hosted five group inquiry-based SA activities across five weeks and generated 29 answers (see Table 5.2). The mean number of weekly answers was 5.8 ($SD = 2.17$), slightly more than the first intervention ($M = 5.25$). Using the same approach as the DBRC1 analysis, to determine the extent the answers supported cognitive presence, each of the 29 answers and five triggers were coded in accordance with Garrison et al.'s (2000) practical inquiry model (see Table 5.2). The weekly answers were distributed across the exploration ($n = 4$; $M = 0.80$; $SD = 1.10$), integration ($n = 17$; $M = 3.40$; $SD = 1.95$), and resolution ($n = 8$; $M = 1.60$; $SD = 1.52$) phases of practical inquiry. Integration represents the highest distribution of practical inquiry, accounting for 50% of inquiry activity, followed by resolution (23.53%) and exploration (11.76%). Aligned to the outcomes of DBRC1, based on the idea that integration and resolution demonstrates a high levels of cognitive presence, the SA activity answers were the product of a productive CoI.

A notable observation, in terms of comparing the stages of practical inquiry to the DBRC1 intervention, is 11.76% of the total answers were encoded as exploration. In contrast, none of the answers for the first intervention were situated at this lowest stage of practical inquiry. This is a surprising result as the SA activities were specifically designed to only allow higher levels of inquiry. However, as I shall explore further below, the week two activity generated two answers that matched the "brain storming" indicator of practical inquiry (Garrison et al., 2001, p. 16). Further contributing to the levels of exploration were the outcomes of the week five SA activity where two groups stated they agreed with another group answer rather than develop their own answers. This met the "information exchange" practical inquiry indicator for exploration (Garrison et al., 2001, p. 16). This was an interesting outcome as the design of Arleno did not allow information exchanges between groups. As such, students re-purposed its design affordances.

A further observation of note, when comparing the outcomes of practical inquiry to DBRC1, is the lower levels of answers reaching the resolution stages. In the first intervention, 44.00% of the answers reached a resolution stage of practical inquiry, as opposed to 23.53% in the second. This result may be because of the theoretical focus of the module chosen for the DBRC2 intervention, and the

students' lack of experience in theoretically focused learning; therefore, presenting a more challenging environment in reaching the highest levels of practical inquiry. Overall, despite the higher levels of exploration and lower levels of resolution, the outcomes of the practical inquiry content analysis align with my own observations and the sentiments from the participants (see Findings 2) that the activities supported deep and meaningful inquiry.

DBRC2: Activity Narrative

To add further meaning to the content analysis presented above, what follows is a summary of the group inquiry-based SA exercises. Aligned with the methods used for DBRC1, I use my field notes, observations, and the activity answers to compose a narrative summary of each weekly activity.

Week 2 was the first week that a group inquiry-based SA activity was run. The focus of the week centred around the key concept that computing could be framed through a research lens. The annotation activity was attached to a six-item research framework developed to help students conduct research focused computing projects. Groups were required to use this framework to construct an idea for a project that would make a good candidate for a final year research-focused dissertation. In total, six groups produced answers spread across exploration ($n = 2$) and integration ($n = 4$) levels of practical inquiry. Overall, the answers tended to be brief, leading to two being categorised as exploration. For instance, group three answered:

> "An app for splitting the bill @ restaurants/ deliveries?"

The above answer only meets the exploration level indicator of "brainstorming" (Garrison et al., 2001, p. 19). The answer establishes a potential project but does not justify or defend it. Four groups did manage to present more defensible project ideas, reaching exploration levels of practical inquiry. For instance, group five answered:

> "Empty homes are often subject to burglaries. A domestic app (also able to work through any explorer) that will mainly control your security at home could solve this problem. It would be able to simulate

> your usual ways of using your lights and sounds, so when you leave your house, it can make people think you are still there. Also, it will allow you to check your cameras live, and it will send you notifications whenever there is a breach."

The above answer was typical of those reaching integration levels of practical inquiry. The answer presents a problem and a solution. As such, it meets the "creating solutions" practical inquiry indicator (Garrison et al., 2001, p. 14). Overall, the week represented a positive start to this cycle of group inquiry-based SA activities; with the majority of answers reaching high levels of cognitive presence.

Week 4 was the next week a group inquiry-based SA activity was run. This week was notable as it was the first week where the feature to add annotation exercises to PDF documents was ready to use. The key concept for the week was surrounding the idea that studies reported on by mainstream media can be misinterpreted, based on questionable evidence, and small sample sizes. To explore these ideas, a paper, widely reported on in mainstream media, was chosen that concluded swearing makes people stronger (Stephens et al., 2018). The annotation exercise was attached to a section in the methods that presented the sample size, which was small (70 participants). The exercise asked the question:

> "This week we are going to focus on the sample size. Can we generalise off this sample? Try to see if they did by reading the conclusion and answer the question below:"

The above question required students to look at the concluding arguments of the paper and evaluate the validity of the claims made. In total, five groups answered the question and answers met the "building on, adding to others' ideas" integration level practical inquiry indicator (Garrison et al., 2001, p. 19). For instance, group four responded:

> "We can't generalize, mainly because the age group isn't very diverse, and cross-cultural studies would be needed to demonstrate the effect of this universally."

Group three presented a contrasting answer:

> "Yes because the definition of generalization is a general statement or concept obtained by inference from specific cases."

While the above answers are contradictory, they both present a justifiable and defensible hypothesis formed through engaging with the paper. As such, both demonstrating high levels of cognitive presence. Further to this, the contrasting answers facilitated lively class-wide debate after the completion of the activity. Overall, this week tentatively showed that SA could be used to engage students in third-party readings as well as teacher-created content. This is a outcome of note as the interview results suggested that many of the students had not encountered academic literature before this class (see Findings 2). As such, the week represented the first time many had been required to explore an academic paper.

Week 6 also took advantage of Arleno's newly implemented PDF annotation feature. The activity was based on the key concept of the importance of research participants explicitly consenting to take part in a study. The annotation exercise was attached to the reported sample of a paper documenting a study where Harvard researchers and Facebook collaborated to manipulate users' news feeds by regulating positive or negative posts (Kramer et al., 2014). The study, conducted on 700,000 people, failed to gain informed consent from the unknowing participants.

Students, in their groups, were asked to construct an argument surrounding the efficacy of such a study. The activity generated nine answers spread across the exploration ($n = 2$), integration ($n = 4$), and resolution ($n = 3$) phases of practical inquiry. The nine responses are the highest recorded across both interventions. Further to this, many of the answers were highly detailed, considering ideas surrounding the terms of service of Facebook, and to what extent research participants had explicitly agreed to these terms. As such, it is perhaps unsurprising that three of the answers achieved the resolution level of practical inquiry. For instance, group four answered:

> "While observed in isolation, the study may seem unethical due to the lack of consent by the 700k 'participants' in any explicit form, it

> must be noted that through legal means, people agree to data mining of social media platforms when they register- however mostly without an acknowledgement of it (who reads terms of agreement anyways?). Nonetheless, research like this could be important, and we suggest that a framework is constructed that allows more explicit informed consent."

The above answer meets the "testable solution" practical inquiry indicator and reaches the highest level of practical inquiry (Garrison et al., 2001, p. 16). It should be noted that the students were not prompted to formulate a solution. As such, the three answers reaching the highest phase of practical inquiry represent relatively isolated examples of multiple non-scaffolded levels of resolution achieved across the study. A further point of note is that two of the groups stated that they "agreed with [P5]", rather than answering the question themselves. This only reaches exploration levels of practical inquiry; however, it shows that other groups' ideas are integrated into wider groups' discussions. Furthermore, it demonstrates the tool being repurposed for use beyond its intended design. Overall, these observations contributed to this week transpiring to be the most interesting across the study.

Week 7 was an eventful week for non-study related issues. My son Arlo was born (the reason the tool is called Arleno), and I commenced two weeks of paternity leave. This meant that I was unable to host the seminars; rather, they were managed by a colleague who had no prior access to Arleno. Further to this, the colleague had a limited technical skill set. As such, the situation presented itself as a test to determine if the tool could be understood and used to facilitate activities by a teacher other than myself.

The weekly focus was on academic writing and centred around the concept that a paragraph is the key unit of writing composition. The annotation activity, embedded into the course content, required groups to critique examples of poorly constructed paragraphs. Six groups responded, and the answers spanned across integration ($n = 4$) and resolution ($n = 2$) levels of practical inquiry, representing high levels of cognitive presence. The integration level answers were effectively in a list format pointing to the errors in each paragraph. However, two groups presented solutions to the errors identified and reached resolution levels of

practical inquiry. For instance, group four's answer was:

> The paragraph suffers from the following:
>
> - chatty talking
> - misspelled words (...)
>
> This could be fixed by:
>
> - Anticipating disagreements and possible counterpoints brought up to your arguments
> - Reading it out to others so you make sure there's no background info that they need which is missing in your explanation (...)

An answer, like the one above, would have required participants to consider what it means to write a good academic paragraph. They would have had to engage with the content and referred to wider sources. Further to offering a meaningful inquiry process, the answer represents an actionable recipe that expands the course content.

In summary, the week validated that Arleno could be used by a teacher, other than myself, to conduct group inquiry-based SA activities that support high levels of cognitive presence. Further to this, the activity demonstrated how the SA activities could be used to expand the content with student-created recipes that can be used by the entire class.

Week 8 was also facilitated by my colleague. In continuing the academic writing theme from week 7, the key concept surrounded the idea that good writing is rewritten. The SA activity was embedded into the course content and required groups to construct a checklist that could be used by their peers to edit academic writing. With only three groups responding, the number of answers represented the lowest across the intervention. A possible explanation is students would have known that the replacement lecturer would be running the session and used this as justification to not attend or engage. Despite the drop in participation, all three answers reached the integration phase of practical inquiry. For example, group three answered:

> "The following is a possible list that students could use:

- Proof reading
- Grammar checking (...)

”

The answer above was typical, and it presents a solution, reaching the integration level of practical inquiry. Like the week seven answers, it offers an actionable recipe that can be used by students to support them in their work. However, unlike week seven, the solutions were tentative with none reaching the resolution levels of practical inquiry.

Week eight was the final week that a group inquiry-based annotation exercise was conducted. Following this week, the module was primarily focused on assessment support. Further to this, I made the decision that I had exposed the students enough to the idea of of the group inquiry-based SA exercises to gain value from their perceptions.

5.3 Conclusion

This chapter has presented the outcomes of a three-year design-based research study with the aim of supporting students in taking a deep-level approach towards engaging in text-based learning materials (Marton and Säljö, 1976). It is a journey that has seen me adopt the role of developer, researcher, and teacher to implement and test a new open-source learning tool, named Arleno. This tool hosts learning materials and allows group inquiry-based SA activities to be embedded into these materials. The chapter began by documenting the extensive development and early exploration that was required to create a new learning tool. I established that a teacher developing a tool can implement pedagogic theory and best learning practice into the design of this tool. However, this flexibility comes at the cost of the considerable time and effort to undertake such a project.

The group inquiry-based activities, supported by Arleno, were refined and tested across two twelve-week interventions (DRBC1 and DBRC2). These interventions saw students engage in nine group inquiry-based SA activities, generating 50 answers. According to the content analysis of the answers conducted using Garrison et al.'s (2000) practical inquiry model, SA activities facilitated by

Arleno can sustain high levels of cognitive presence. Furthermore, it allowed effective teaching presence through the facilitation of content and scaffolding of inquiry focused SA activities that required minimal direct instruction. Overall, this chapter has demonstrated the process of creating a learning solution to effectively support the teaching and cognitive constructs of a CoI.

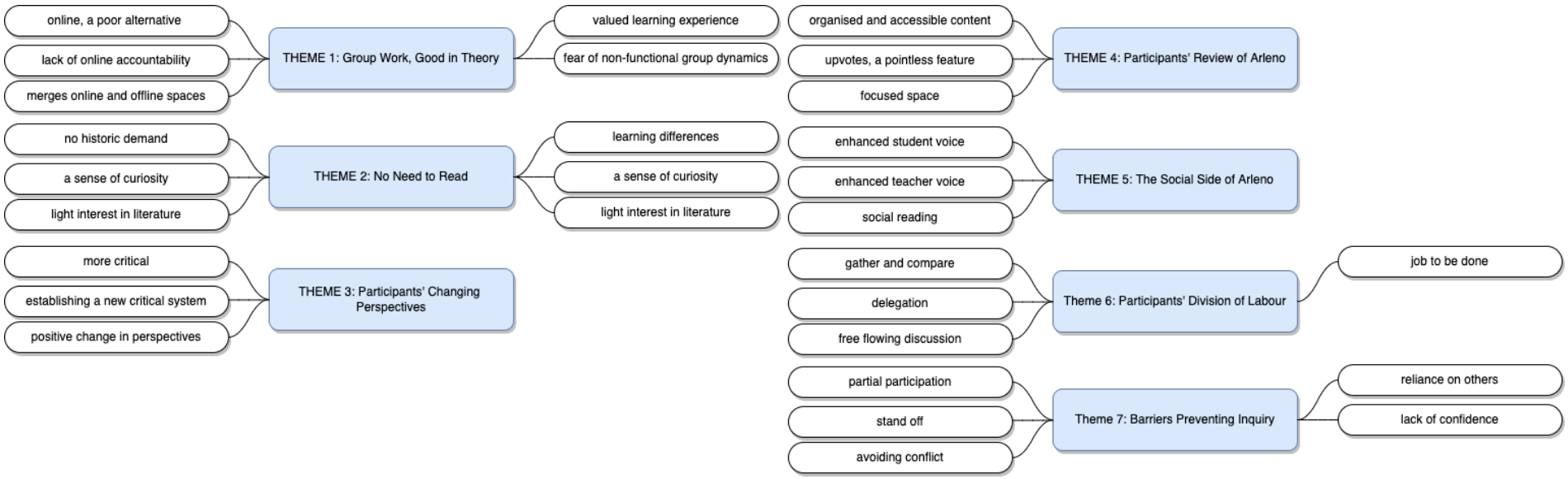

Figure 5.5: Thematic diagram of the themes resulting from the interview data.

Chapter 6: Findings 2. The Participants' Perspectives

The previous chapter drew on my observations and analysis of the outcomes of the SA activities to address research questions one, two, and three. In doing so, I presented a design narrative documenting the process of developing and conducting two DBR interventions (DBRC1 and DBRC2). This chapter moves on to evaluate the DBRC1 and DBRC2 interventions from the perspective of participating students.

Participants' perspectives were gathered through two post-intervention rounds of semi-structured interviews. In total, 24 participants were interviewed, 12 after each intervention. In the proceeding account, participants labelled P1 - P12 were interviewed after the DBRC1 intervention, and those labelled P13 - P24 after the DBRC2 intervention. The analysis of these interviews was combined into seven top-level themes (see Figure 5.5). This chapter organises the themes to answer research questions four and five:

4. What were students' historic perceptions towards text-based learning materials and group work; and, in terms of text-based learning materials, how did the interventions change these perceptions?

5. What were students' perceptions and experiences of using Arleno in terms of the group inquiry-based SA process followed, the social presence supported, and the usability?

Question four explores the historic perceptions that students brought into the study and considers how engaging with the DBRC interventions changed these perceptions. Question five takes an evaluative stance, exploring perceptions and experiences surrounding the use of Arleno, and the group inquiry-based SA activities it supported.

6.1 Historic Perceptions of Group Work

Arleno was designed to support, through SA activities, a group-based inquiry process. As such, to further refine design choices, part of the interview protocol for the DBRC1 cycle explored students' ingrained historic perceptions towards group work. I used these insights to inform activity and tool design choices moving into DBRC2. This section addresses the group aspect of research question four by presenting, "THEME 1: Group Work, Good In Theory". In doing so, I provide an insight into the perceptions that students carried into the interventions.

6.1.1 THEME 1: Group Work, Good in Theory

This theme captures the duality of the relationship that participants have with group work. It shows that on the one hand, they valued the learning potential; on the other, the idea of group work evokes negative emotions such as dread and fear. Further to this, it captures the idea that an online setting can worsen these emotions.

The students indicated that they recognised the value of the collaborative incites and the learning opportunities that group work can offer (P1, P2, P3, P4, P5, P6, P7, and P12). For instance, P2 stated:

> "I think everyone has value. Every student coming into it even if they don't talk much, they might talk a little bit and it will give you an idea."

The comment above suggests that participants, regardless of how active they are in a group setting, can still offer value.

Other students were more specific in the value that group work offers. They indicated that they appreciated the collectively constructed ideas, widening of perspectives, and increased confidence gained through collaborative activities. For instance, P4 remarked:

> "You get an opportunity to discuss a different perspective that you would not normally get on your own."

P5 was more focused on the value in terms of the individual knowledge construction that they can extract from a group setting:

> "If I don't have much knowledge on something; I just pull off of other people's knowledge."

Interestingly, P7 commented that group work offers value beyond knowledge construction. They remarked, about group work, that, "it can help build up my confidence". Overall, it was clear that the students valued the learning opportunities that group work can offer.

Above, we have seen that students appreciate the theoretical value of group work. However, they are conflicted against the practical reality of working in groups, as the theoretical benefits are often not realised (P2, P3, P5, P6, P11, and P12). The very anticipation of group work can give rise to strong emotions. For P12, it makes them "nervous and scared", while P3 and P2 have feelings of "dread". These emotions may be caused by students experiencing "so many instances where group work goes badly" (P3).

Students indicated there is also the anxiety of not knowing the extent that group participants are willing to divide labour. For instance, P11 stated that their immediate thought when required to undertake group work is:

> "I hope I don't get paired with people that are just not going to pull their weight."

Often the negative emotions do not subside once groups have been formed. Students indicated that there is an inherent "fear of being wrong" in front of a group (P1, P3, and P13). Even if they know being wrong is part of learning, the fear barrier still presents itself. For instance, P3 commented:

> "It is not a big deal being wrong and part of learning, but perhaps psychologically we do not want to look stupid."

Overall, these comments suggest that the idea and practical reality of participating in group work are daunting prospects for students.

The negative aspects of working in a group, explored above, seem to be exacerbated when the group setting is online. Students see such a setting as a poor

alternative to the traditional face-to-face equivalent (P1, P3, P5, P6, and P11). The depreciation of the online value of group work seems to be related to the idea of presence.

Participants can hide behind turned-off cameras, and there is a feeling they are less present and accountable. For instance, P3 stated:

> "I think when it's in person, obviously, it's a bit easier for people to engage, because I think they feel like they're being watched more."

Likewise, P6 remarked:

> "If you're in a class, physically with them, I suppose there's more of a pressure on them to try and do stuff."

The ability to hide behind a turned off camera when working in online groups can also cause confusion and disorientation. For instance, P5 stated:

> "When there is limited interaction, it is impossible to tell whether that's through problems with microphones or just not an active participant."

Further signs of confusion were shown by P11:

> "Often you feel like people might have joined the breakout room and then cleared off, you just never know."

The above comments suggest that online group work merges online and offline spaces. However, students are seldom willing to share the offline spaces that they occupy, and it can be unclear who is present in the online space. As such, this heightens the negative anticipation of joining a group.

Overall, this theme has presented the idea that the students appreciate the theoretical deeper level learning opportunities that group work can offer. However, the value of group work is only realised when the group itself is functional, and in an education setting this appears to rarely be the case. As such, the anticipation of a non-functioning group may outweigh any perceived value and give way to strong negative emotions such as dread, fear, and anxiety.

6.2 Historic and Changing Perceptions Towards Text-Based Learning Materials

The aim of the DBR study was to develop a solution to engage students in text-based learning materials. In doing so, the ambition was to enhance their appreciation and criticality towards ideas represented in this medium. To explore the ways in which this aim was met, this section answers the aspects of RQ3 surrounding students' historic and changing perceptions towards text-based learning materials. In addressing these areas, I go on to present two themes: "No Need to Read" and "Widening of Perspectives". These themes capture the ideas that students arrived at the interventions with little exposure to text-based learning materials. However, the process of using Arleno to engage in group inquiry-based SA activities widened their perspectives and criticality.

6.2.1 THEME 2: No Need to Read

The students participating in the interventions can be categorised as non-traditional students and are undertaking computing courses that are largely applied. The focus is on how to complete industry-aligned technical tasks, as opposed to exploring the underpinning theories that apply to the "why" behind this practice-based activity. This theme captures the idea that, given this style of learning, there is little need to engage in theory or theoretically focused readings. However, the theme also goes on to establish that the students are curious individuals with a desire to learn. In other words, they are open to exploring the theories underpinning practice; however, before participating in the interventions they had little in the way of exposure to such ideas.

As established above, the participants are considered 'non-traditional'. Many of them are first-generation students and have taken alternative academic routes into higher education. Perhaps in line with the misplaced stereotype, one student outwardly identified as not being curious; P13 remarked:

> "I am not really a deep thinker I don't really like to go into the depth of things."

However, it would be a mistake to generalise the above sentiment across all

students, as most showed an appreciation towards learning and identified as curious people. For instance, P19 and P22 were emphatic with regards to the importance of curiosity and learning in their lives. P19 stated the popular adage, "I think the more we know, the more power we have" and P22 remarked that "one of [their] fears in life is one day not being able to mentally explore and find things out."

Further students were more specific about the application of their curiosity. For instance, P17 stated:

> "I'm curious about the things I enjoy. When I don't enjoy something, I don't do enough research about it."

Likewise, P19 also identified as directing their curiosity towards specific topics they are interested in, stating:

> "I mostly find scientific stuff interesting, anything about space."

The above comments establish that the students are indeed curious individuals. However, prior to participating in the intervention, the learning outcomes of their courses meant that there was little need to apply their curiosity towards theoretical ideas or academic literature. For instance, P18, who was reaching the end of their second year of a three-year course, expressed that there was no historic need to consider wider text-based concepts:

> "Everything that I've learned was a method of how to do something we never had to do anything theoretical or read anything."

It appears that this lack of exposure and understanding shown towards text-based ideas shows in assessment outcomes. Students, when required to construct assessed reports, expressed that there is little in the way of extrinsic grade motivation to engage in academic literature. For instance, when asked why they have never used academic sources, P22 remarked:

> "I probably should have used them for my previous reports. However, it's just something that hasn't been brought to me, so I didn't really think about it at the time."

Further to the above comment, P15, who had been receiving top grades, stated they regularly used in their reports, what they now know to be, low-quality sources such as blogs and Wikipedia. When questioned why this was the case, they responded:

> "Honestly, no one told me that I was wrong, no one has ever said anything."

The above comments have begun to establish that lack of extrinsic motivators and the practical nature of the courses lead to students not engaging in text-based learning materials. However, it would be an oversimplification to believe that these are the only reasons. For instance, two students cited learning differences as a reason for not engaging with the literature (P22 and P16). P22 remarked:

> "I never really read anything, because I'm dyslexic."

and P16 stated:

> "Because I have ADHD I could not sit down and concentrate for more than 10 minutes on reading."

Further to the above comment, there was a student who stated they were, "too busy [with paid work commitments] to read" (P15). Finally, a student stated the reason they did not read was that "[they are] really lazy" (P21). Overall, it can therefore be established that a culmination of little extrinsic motivation, lack of theory in course content, learning differences, lack of time, and lack of motivation are all reasons why, prior to partaking in the intervention, students may not engage with text-based learning materials.

6.2.2 THEME 3: Participants' Changing Perspectives

The above theme revealed that students had little in the way of historic exposure to text-based learning materials. This theme addresses the outcomes of the DBR interventions in terms of the change in perspectives they supported. It captures the idea that many students reported a positive change in perspective with regards

to the levels of criticality they showed towards text-based materials. Furthermore, they started operationalising this newly found criticality through building systems to allow them to evaluate text-based information. Overall, this change in perspective captures one of the key outcomes of the DBR study.

It appears that the interventions have improved the criticality that students show towards text-based sources. For instance, P15 remarked:

> "The process has 100% made me think differently about academic literature and sources. I would definitely use better sources and not Wikipedia or blogs".

Likewise, P17, in talking about the outcomes of engaging in group inquiry-based SA activities stated:

> "It's changed my point of view and how I consider things and I now consider the difference between academic sources and more casual sources."

P22 also showed newly found levels of criticality towards literature, they remarked:

> "I now know what to use, and I know what I need to look for. Honestly, the activities have been very helpful."

Overall, it appears that the outcomes of the interventions have supported students in becoming more critical towards text-based materials and information presented to them. Moreover, the above comments suggest that this new perspective will be carried forward in their lives.

Interestingly, some of the students suggested that they have now started to develop systems to operationalise their newly found levels of criticality. For instance, P17 stated that when trying to validate the legitimacy of facts:

> "I have now developed a system where I find three or four journalistic sources and compare them against each other. Further to this, I now always try and find first-hand accounts of any underlying studies."

P20 also indicated that they had started to develop a process for locating good quality information, they remarked:

> "I now use Google Scholar and Science Direct to locate sources. Next, I look at aspects such as sample size and the claims the authors are making based on this sample."

The above comments suggest that the SA activities have motivated students to acquire systems to evaluate reported information. As such, it appears that the interventions have contributed to changes in the way that students understand and interact with literature.

6.3 Perceptions of Arleno

I now move away from the broad outcomes explored above to focus on the perceptions and processes surrounding Arleno and the group inquiry-based SA activities it supported. In doing so, I answer RQ5 by first considering the overall usability and levels of social presence Arleno supported. Next, by exploring the reported group process followed when engaging with the SA activities.

6.3.1 THEME 4: Participants' Review of Arleno

This theme explores the students' perceptions of Arleno. To recap, Arleno hosts content and SA exercises attached to this content. The overall study is primarily focused on the SA functionality. However, by their very nature, annotations are embedded in the content; it became clear, early in the interview process, that participants did not distinguish the content from the annotations. As such, the overall perceptions surrounding the hosting of content and embedded annotations are captured in this theme. In viewing Arleno through a wide lens, considering annotations and content, this theme starts with the broad content-level features of Arleno then moves onto specific SA features.

In terms of hosting content, students suggested that Arleno organised learning materials in an accessible and useable way (P2, P7, and P9). For instance, P9 stated:

> "I like the navigation as it lets you know what you're looking for and you can easily find topics and material. It's not just like Week 1, Week 2, Week 3, you really know what topics you did that week, so it's helpful to find those."

P9's sentiment suggests that the way in which Arleno indexes and organises course content is well received (see Figure 4.1; feature 1; p. 70). Further students also remarked about content organisation. For instance, P2 stated, "I always knew that I could find the content that I needed". Further to the content being easily discoverable, it was also straight forward to access with students reporting that it was "quick and easy" to use and access Arleno (P2, P7, and P9). Overall, these comments suggest that Arleno provides the usability affordances of well-structured and easily accessible content.

Moving on to consider the annotations in relation to the content, in terms of displaying the activity attached to the annotation, a design choice was made to facilitate the annotation activity in a pop-over box, as opposed to limiting the activity to a sidebar (see Figure 4.1; p. 70). This design choice appears to have been validated by the students. For instance, P4 remarked that the annotation process is:

> "A really good way of formatting a discussion point. The tutor can pose a question and it allows the students to remember what the question is connected to."

Adding further insights surrounding the annotation features, P2 stated:

> "I did like the fact that it was quite focused. The annotation area was a talking point that we could sort of relate information to. I also always knew the content that we should focus on."

In summary, it appears that Arleno has presented itself as a positive addition to the classroom. From a facilitation perspective, students were positive with regards to the overall design and usability of the tool. Content could be easily found, and the tool had little in the way of usage barriers. In terms of the SA activity being facilitated in a pop-over window, students appreciated that it offered a focused

space for discussion that was set against the specific sections of text-based material.

Above, I have established that Arleno was well received. However, while there were no outwardly negative comments, students appeared indifferent about the feature allowing answers to be upvoted (see Figure 4.1; feature 5; p. 70). This feature was a design choice that had the intention of serving two purposes. First, to allow an easy way to interact with answers. Second, it allowed the answers to be displayed in an order descending by the number of upvotes. However, it appears that this feature did not meet the intended design aspirations. For instance, P4 stated:

> "The upvoting could be troublesome. What if I share something, and I get no votes, this may not actually mean my answer is bad. You need to have a purpose for doing it. Rather than having it there for the sake of it. What value does it serve as part of the discourse."

The above comment suggests that the feature may not serve a purpose in supporting discourse. Further to this, it implies that the number of upvotes may not accurately represent the quality of the answer. Adding further evidence to the idea of upvotes being unrepresentative of an answer's quality was the sentiment of P2 who was aware of one participant who was, "upvoting his own stuff and his friend's stuff".

Overall, it appears that the upvotes can be easily manipulated and may not represent a democratic view on the quality of the answers. Further to this, it may cause anxiety surrounding the idea that an answer may not get votes.

Two students voiced interesting ideas to address the design flaws with the upvote feature (P6 and P7). Their ideas centred around allowing more flexible types of reactions, as opposed to just the ability to upvote. P6 suggested that the idea of an upvote has:

> "Specific connotations of agreement with an answer rather than rewarding a well-constructed answer."

P6 went on to suggest that a feature that allows others to "acknowledge that [they have] read the answer" may evoke more interaction. P7 also suggested

they would also like to have more flexibility than just an upvote, stating it would be good to have "agree and disagree". In summary, it appears that the upvote feature needs to be integrated into the pedagogical design of the activity and the purpose of it made clear. Further to this, it should be made more flexible to allow a wider range of reactions to a given answer.

6.3.2 THEME 5: The Social Side of Arleno

This theme captures the idea that students perceived Arleno to support high levels of social presence, enhancing both the student and teacher voice. This was supported by the process surrounding SA and what I call the presence detector. The presence detector projects students profile pictures on the screen when they are reading learning material (see Figure 4.1; p. 70; feature 2).

The presence detector was a secondary feature idea; however, it was well-received. It provided students with a sense of connection and reassurance that they were not the only ones reading the learning-materials (P2, P3, P4, P6, and P9). P3 articulated this idea well, stating that:

> "It is good to know that other people are looking at stuff at the same time. I think, particularly when you're learning in isolation, it can be very easy to think that you're the only one that has issues."

P6 echoed the above sentiment:

> "I just thought it was pretty good. It shows you that other people are also working on the content. It is especially reassuring when you are looking at it at like 2:00 am and others are also working."

The above comments suggest that this simple feature can foster a sense of togetherness and support social presence. It allows students, with no effort, to project their presence onto the learning space, connecting their learning endeavours with a wider community.

Social presence was also supported through the features surrounding the process of the group inquiry-based SA activities. These features provided the affordance of enhancing both the students' and teacher's voices.

The teacher's voice is enhanced through the process of anchoring SA activities to course material. Students were drawn to the highlighted sections that contained the SA activity and considered this content important. For instance, P6 said that:

> "I knew a section highlighted with an annotation was important and required more of my attention."

Likewise, P1 also noted that the annotated sections drew their attention and sparked further inquiry:

> "I think the highlighted section very clearly showed importance, and also that there was something to click which would reveal further information."

Above, I have established that using Arleno to facilitate SA activities enhances the teacher's voice. The process of engaging with these activities appears to have the affordance of enhancing the students' voice. This was through the mechanics of SA allowing students to expand on the content highlighted by the teacher. In other words, the SA activities led to an indelible extension to the course content with collective ideas and perspectives that can be later reflected upon. In essence, these added perspectives represent an enhanced student voice. Showing appreciation towards this enhanced voice, P6 said:

> "It was actually quite nice to read what other people were thinking about the highlighted sections of content."

This above idea of accessing third-party thoughts was also noted by P9:

> "The [annotation part] is really nice because then you see what other people think and you can use it to further formulate your own ideas."

Overall, the comments above present the idea that outcomes to the group inquiry-based SA activities are permanently captured and reflected on by the wider learning community. Students and teachers, therefore, have the means to

communicate, externalise, and share ideas about course content in way that, without SA, would be not possible. As such, the process of engaging with SA activities provides the affordance of enhancing the students' voices. Overall, this affordance adds to the enhanced teacher's voice and the connecting effect of the presence detector to underpinning social presence.

6.4 Group Inquiry-based SA Activities Process

This final section considers the aspects of research question five surrounding the process of engaging in group inquiry-based SA activities facilitated by Arleno. In exploring this idea, two themes are presented: "Theme 6: Participants' Division of Labour" and "Theme 7: Barriers Preventing Inquiry". The former theme identifies three productive inquiry-based strategies that groups used to engage in the SA activities. The latter, reveals barriers that could prevent these productive group inquiry strategies from occurring.

6.4.1 THEME 6: Participants' Division of Labour

This theme provides insights into how labour was divided amongst groups in the completion of the inquiry-based SA activities. I present three approaches that followed an effective inquiry process (Garrison et al., 2000). I have named these approaches "gather and compare", "delegation", and "free-flowing discussion". Overall, it appears the majority of groups followed one of these three strategies and achieved high levels of inquiry. This aligns with the content analysis of the SA answers that indicated high levels of practical inquiry were supported across both interventions (see Findings 1). However, one further approach was identified that saw the activity as just another job to get through; this approach, which I have named "a job to be done" did not appear to support high levels of practical inquiry. Below, I briefly explore each of these four approaches.

Gather and compare is a technique where students would "work individually" on the inquiry-focused question (P.3). They would then gather and compare their answers and either use the best individual answer or construct a collaborative answer. An example of this method is when P6's group undertook a SA task where they were required to construct a model project problem statement.

In reference to the group process followed, P6 stated:

> "Each of us would try and draft an answer. We would then discuss and then post the one which we thought was best." (P.6)

A further example of this strategy was demonstrated by P15:

> "We would normally all make a list of bullet points that would address the question. Then, we would discuss, and perhaps combine the best points. Normally, the writer with the most points or prior knowledge would then be nominated to answer the question."

While the method described above is time-consuming, it requires the students to understand and discuss their answers and is an example of a functional inquiry process.

Delegation presents a more time-efficient technique. This strategy involved students splitting the SA tasks into sections that could be delegated. For instance, P7 stated, when their group had to complete an SA task surrounding an academic paper they:

> "Would end up splitting the paper into sections. For example, one of us might take a look at the abstract and another person the results. To answer the question, we would then come together and discuss our findings, and aim to get three or four good points down."

Also aligning to the strategy of delegation, P1 noted that they were in a group where distinct roles were assigned. In reference to their group process, they stated:

> "We kind of assigned ourselves each a different role. For instance, one person might have to work on reading the paper, a further person might be tasked with finding wider evidence."

Interestingly, it appeared that some groups were able to use the delegation strategy to adopt roles that served to support individual weaknesses (P15 and P16). For instance, P16 noted:

> "I'm quite good at skim reading. However, P22, who was in my group, can't skim read at all as he has ADHD, so I do the reading for them."

P19 also alluded to group members complimenting each other; they stated that:

> "With P13 not being a native English speaker, he was able to ask the group what certain words meant and how they are being used."

Above, we see that delegation can be used to complement other group members' weaknesses and be more performant in completing the task than the "gather and compare" strategy. Furthermore, adopting this strategy and assigning roles requires the students to collectively understand the tasks. As such, this strategy could be one of the most effective means of inquiry.

Free Flowing was the final productive strategy identified. This appeared to be the most common approach and would involve groups undertaking free-flowing discussion. For instance, P9's group would approach SA activities by:

> "Reading around what the paper was about, and just kind of discussing and bouncing ideas off each other with regards to what we can say about the question that you asked. Mostly we agreed, but every so often, there was some clear disagreements."

P21's group had a similar free-flowing approach demonstrated above. However, they appear to have had a more developed answer formulation strategy. P21 stated, that the discussion started with:

> "People giving their random thoughts and we would note which points were most relevant to the question."

They would then check to see which other groups had responded to the inquiry activity and see:

> "If someone has already come up with a similar answer that represents our ideas, and we could agree with them."

The above comment captures an interesting outcome. It appears that an inquiry process has taken place; however, this may not be captured through the textual outcomes of the activity. Furthermore, it is interesting that the outcomes from wider groups are being integrated into the free-flowing strategy; as such, this strategy represents a positive inquiry process

Above, I have identified three group approaches that align with the values supporting an effective inquiry process. However, a further approach was identified where some students viewed the group inquiry-based SA tasks as a **job to be done**. In other words, it was something they just wanted to get over and done with. For example, P14 saw the SA tasks as, "you know it was just one of those tasks". In response to the group process followed they would often address the group with:

> "Let's just get this done, does anyone have any idea what to do? Someone would normally answer, and we were like, okay, fine just put that answer down and we are done with it."

The above process shows low level of practical inquiry. Discussion seems to only be centred around getting the task done as quickly as possible. Adding further insight to this approach, P20, who was in the same group as P14, stated:

> "Some people are just trying to leave the session as soon as possible; they just want the tasks over and done with."

P1, who was in a different group to P20 and P14, also made a similar remark:

> "If the group dynamic is bad, I just want to get [the task] over and done with."

While P1's remark appears similar to P20's there is a subtle difference in the ways the groups were formed. P1 was interviewed after the first intervention where groups were randomly assigned; as such, the group dynamic was highly variable. P20 was interviewed after the second intervention, where groups were self-selected. A further point of note, P20 was a motivated student and wanted to follow an inquiry-based process. However, the dynamic of the group they chose did not lend itself to this process. On reflecting on the group selection, P20 commented:

> "In hindsight, I probably would have preferred to just have you have organised the groups with complete disregard to kind of friendship circles and stuff."

The above comment shows that one motivated student cannot necessarily convince fellow students that the task is worthwhile. It also suggests that familiarity and friendship may not always presuppose a good inquiry-based group dynamic. However, when groups are randomly assigned there appears to be a high level of variability in the group dynamic. This can also lead to students wanting to get the task done as quickly as possible.

Overall, while a "Job to Be Done" presents an ineffective inquiry process, it appears that most students followed the former three strategies that supported a functional inquiry process. In considering these functional group strategies explored above, there were two interesting educational affordances discovered. First, Arleno could be used to broker communications between groups and support the inquiry process. Second, students were able to adopt roles that would support other students' weaknesses.

6.4.2 THEME 7: Barriers Preventing Inquiry

Above, I established three strategies that led to productive group-based inquiry. This final theme explores barriers that could prevent this productive inquiry from taking place. The issues identified are avoiding conflict, partial participation, and a stand-off. I explore each of these facilitation issues below.

Avoiding conflict is where students are not willing to disagree with their peers (P12, P15, and P22). However, disagreement and respectful debate form a fundamental part of the inquiry process. Therefore, avoiding this type of discourse can cause facilitation issues. The reason for this avoidance could be to ensure the group process is over with as quickly as possible. However, there were also instances of students not having the confidence to debate ideas. For example, P15 stated:

> "I think some people hold back on maybe disagreeing and putting their own input into the scenario, as they are too shy or don't have the confidence to speak up."

Likewise, P20 remarked:

> "I don't really want to disagree with anyone, because sometimes I'm just shy."

The above statements present the idea that the absence of productive group outcomes may not be because students are disengaged. Rather, it could be they do not have the confidence to participate in the group-based inquiry process.

As we have seen above, some students may be unwilling to engage in conflict. However, there were reported instances where there would be no discourse at all. An unexpected outcome of the group process was some students reported at the start of the group session they would sit in complete silence, sometimes for extended periods of time (P1, P2, P5, and P11). I refer to this facilitation issue as a **stand-off**.

The stand-off was primarily an issue in the DBRC1 intervention. Groups were randomly assigned for each SA activity. This meant that when students entered their online breakout rooms to participate in the task, they needed to orientate themselves with their group members. However, there seem to be instances where fellow group members are not willing to engage in orientation and, instead, sit in silence. For example, P1 stated:

> "When I entered the breakout room, sometimes for a good 5-10 minutes, no one speaks."

The above statement suggests that the stand-off can last for dramatically long periods of time.

An additional reason may be a vicious cycle of the students thinking no one is speaking and, if I speak, I will not get a response. For instance, P2 remarked:

> "No one is talking and if you talk and no one responds you feel stupid, so I just wait for someone else to start talking."

A further reason may be the time lag in people managing to join the breakout room. For instance, P5 gave an example where they were waiting "a long time for people to actually join the room". They went on to state that:

> "Even once there was a room full of people, still no one was speaking. People did not have their cameras on, and I think people were confused if anyone was there."

The above statement suggests that participants' unwillingness to project their presence onto the online space can cause confusion resulting in a stand-off.

Overall, it can be concluded that it may be a lack of familiarity, confusion about the roles that students should be assuming, and the awkwardness of online discussion that is causing this stand-off.

To solve the issue of a stand-off, the design choice was made to allow students to self-select their groups for the DBRC2 intervention. They remained in their chosen groups for all SA tasks. When considering the group selection process, several students suggested that they chose their groups as they shared a similar outlook or had existing friendships (P12, P22, and P21). For instance, P21 was part of a group that consisted of people from the "same house" or people who wanted to do a "similar [assessment] topic". P22 also chose a group consisting of like-minded individuals choosing peers taking their course. They stated:

> "There were only four of us, so it was good that we were all together, because then we can talk about things relate to us."

Overall, it is perhaps not surprising, that like-minded people will be drawn to work together. Also, the familiarity of team members meant the stand-off, discussed above, was not reported in the DBRC2 intervention.

While the process of self-selecting groups solved the problem of an initial stand-off, it did not prevent the facilitation issue of **partial participation** occurring. Partial participation is where one or more group members are inactive and was observed widely by students across both interventions. For instance, P19 referred to the challenge partial participation:

> "it's a bit harder to get everyone to interact at the same time, often it's just me and one other person taking."

Likewise, P14 was in a group of six; however, they stated:

"Mostly it was just me and [P15] participating and then sometimes another group member would show up."

The above comments suggest that there are often instances when one or more group members are not contributing to the SA task. This lack of participation can lead to resentment; for instance, P2 stated:

"[showing frustration] I am doing most of the work, a lot more than the other person."

The above statement suggests that partial group participation can be a frustrating aspect of group-based inquiry.

It is hard to determine the cause of partial participation. There is evidence to suggest some individuals struggle to navigate the group dynamic. For instance, P7 stated:

"Some people are a lot quieter, some people can't stop talking, and some people like to take control, and it is hard to know where I fit. Often, I just sit there."

A further potential cause of partial participation could be where students are familiar with group members and can rely on other people to do the work for them. For example, P20 was part of the DBRC2 intervention and able to self-select their group. However, they were dissatisfied with some group members being able to rely on others to do the work. They stated that they would have rather been assigned randomly to a group as:

"Not knowing how everyone works means we would all have to pull our weight, rather than people relying on the person they know will do the work."

Likewise, P16 suggested that lack of familiarity may prevent aspects of partial participation. They stated:

"I think working outside of friendship circles kind of motivates you to represent yourself."

Finally, there was also evidence to suggest that participation, or lack of it, may be dependent on the perceived value of the SA topic. For instance, P20 stated:

> "The level of participation really depends on what the task is. If people think the task is interesting or valuable, they are more likely to participate."

In conclusion, it appears that not being able to navigate a group dynamic, an over-reliance on individuals who others know will do the work for them, lack of perceived value in the task, and an unwillingness to engage in critical discourse may cause partial participation or even a complete stand-off.

6.5 The Overall Difference and Similarities Between the Two Interventions

The above themes capture the outcomes of the interviews from the DBRC1 and DBRC2 interview rounds. I combined the themes into a single chapter after the emergent codes from both interview data sets appeared similar. There were, however, two subtle differences in learners' perspectives and levels of cognitive presence between the two interventions that I shall briefly explore below.

First, when comparing the practical inquiry levels between DBRC1 and DBRC2, the content analyses of DBRC1 intervention's SA inquiry-based activity answers indicated higher levels of cognitive presence than DBRC2. I attributed the lower levels of practical inquiry in the DBRC2 intervention to the theoretical focus of the research methods module that served as the setting; this resulted in it being harder to develop practical, real-world solutions than the practically-focused database programming setting of the DBRC-1 intervention. Nonetheless, learners reported increased criticality and productive inquiry processes across both interventions. Overall, I concluded that the levels of practical inquiry do not directly correlate to levels of self-reported learning.

Second, there were differences in the group formation strategy for the inquiry-based SA activities across DBRC1 and DBRC2. For DBRC1, I experimented with randomly assigning students to a new group for each inquiry-based SA activity. However, the interviews revealed that students had to re-form social presence for each activity; this proved challenging to such an extent

that some participants reported a stand-off situation where groups would sit in the break-out rooms in silence, sometimes for extended periods. Based on this feedback, in the second intervention, I chose the strategy of allowing students to self-form groups at the start of the module, remaining in their groups for the entirety of group inquiry-based SA activities. Allowing groups to self-form over the long term solved the issue of stand-off. In summary, enabling students to self-form groups that remained in place over the course of the module supported higher levels of social presence than randomly assigned short-term groups.

6.6 Conclusion

This chapter has presented the outcomes of 24 semi-structured interviews conducted with students participating in the DBRC1 and DBRC2 interventions. The objective of the interventions was to refine and test the group inquiry-based SA activities, based on Arleno, developed to engage computing students critically in text-based materials. Overall, the interviews revealed the group inquiry-based SA activities were a welcome addition to the classroom. Participants remarked Arleno offered high levels of usability and social presence. Further to this, it provided a focused space for the SA activities. The most striking outcome was that engaging in group inquiry-based SA activities, supported by Arleno, heightened students' reported levels of criticality. In operationalising their newfound criticality, some students have started to develop systems to critically evaluate the quality of text-based sources. This is particularly meaningful as the interviews revealed that students arrived on the interventions with little in the way of historic need to engage critically with text-based learning materials. Further to this, they had largely had negative experiences of group work in an educational setting, especially when the group setting is online. As such, the interventions have overcome these engrained experiences.

Beyond this broad outcome, some further points of note surrounding Arleno and the SA process were discovered. First, groups largely followed one of three productive inquiry approaches that I named "gather and compare", "delegation", and "free flowing". However, these productive approaches are at odds with facilitation issues mostly surrounding levels of participation and seeing the group

inquiry-based activities as a job to be done. Second, Arleno supports an SA process offering high-levels of social presence (Garrison et al., 1999). The teacher's and students' voices are enhanced though SA enabling a means of communication, anchored to text-based content, that would be otherwise unavailable. Finally, further to the enhanced voice, an unexpected social affordance was that projecting readers' profile pictures on the text-based material fostered a sense of togetherness. Overall, these sentiments suggest that Arleno possesses the educational and social affordances of enabling students to productively engage in group inquiry-based SA activities that has the outcome of supporting a critical CoI.

Chapter 7: Discussion

This section interprets the findings presented above. First, I revisit each research question, considering the answers in the context of wider research. Next, I consider the connection between this study's aim of deep-level engagement in text-based resources and the CoI's three presences. Finally, I conclude by listing design principles relating to the development, design, and use of the learning solution created for this research. The principles are of use to teachers and learning designers looking to support deep-level engagement in text-based learning materials in wider settings.

7.1 RQ1: How was the design and development of the open-source learning tool, Arleno, managed?

Answering the above question revealed that to develop and test a new learning tool it was necessary to assume the roles of programmer, teacher, and researcher. In doing so, I have demonstrated how an individual can bring together multiple roles to develop a solution to an identified problem in their learning setting. Capturing the significance of this undertaking, Dillenbourg and Jermann (2010) noted that lecturers in the field of technology-enhanced learning assume the roles of teacher and researcher; however, these roles often function in isolation. In conducting this current research, I added the further role of a programmer to create a successful learning solution that addressed the challenge of supporting learners in taking Marton and Säljö's (1976) deep-level approach towards engaging in text-based learning materials.

In assuming multiple roles, I have shown how to progress through decreasing levels of abstraction by mapping a theoretical framework to a concrete implementation of a new learning tool. I grounded the theoretical framework on my commitment to Vygotsky's (1980) ideas surrounding social constructivism. I

operationalised this commitment through Garrison et al.'s (1999) CoI. The CoI advises on a practical inquiry process to support deep and meaningful learning in an online text-based environment. Finally, to assist with implementation and evaluation, I explored the literature to establish the latest design principles pertaining to CMC and then mapped these principles to SA features. Overall, the combination of this process represents decreasing levels of abstraction and shows how sound socio-constructivist learning theory can provide a basis for a new learning tool.

While this research has established how an individual can assume multiple roles to develop a new open-source learning tool, the developer logs and reflective accounts revealed that assuming these roles was complex and time-consuming. Both the DBRC1 and DBRC2 design and construction cycles overran. Furthermore, the first version of Arleno, tested in the DBRC1 intervention, only supported annotation activities attached to teacher-created content, not third-party PDF documents. Given these experiences, it is unsurprising that the majority of studies creating new learning tools are rudimentary in design and intended for use in a single study (Zarzour and Sellami, 2017; Shin et al., 2018; Chan and Pow, 2020; Gayoso-Cabada et al., 2019). For instance, the developers of the widely used SA tool NotaBene noted that the first version had a "very clunky" user experience (Zyto et al., 2012). Likewise, Kreijns (2004) remarked that, when creating a new social learning tool for a PhD project, time constraints meant that the user interface was basic. In summary, developing learning tools is a time-consuming undertaking and sacrifices in the intended functionality often need to be made to address time and budgetary constraints.

To manage the complexity of the design process, extending the design and construction phases of the DBR cycles with an agile design thinking approach proved helpful (Pereira and Russo, 2018). Integrating this approach into DBR required representing design prepositions as user stories prioritised in terms of importance to the overall solution. The user stories were then implemented as stand-alone, high-quality, components. Components could be tested in isolation and incrementally added to the solution, even if an intervention was in progress. This is well aligned to the DBR idea that the functionality of a solution should

increase over time (McKenney and Reeves, 2012).

Regarding the outcome of the development process, intervention participants indicated they found that Arleno organised learning materials and annotation exercises attached to these materials in a usable and accessible way. From a teaching point of view, minimal direct instruction and guidance were required to enable learners to use the tool. In contrast, wider studies have shown that often teachers spend significant time orientating learners with new discussion or SA tools (Harris, 2017; Cesareni et al., 2015; Butz and Stupnisky, 2017). As such, incorporating an agile approach into DRB ensured Arleno provided an intuitive user experience.

7.2 RQ2: To what extent did the outcomes of the group inquiry-based SA activities, facilitated by Arleno, support cognitive presence?

In answering the above question, I used Garrison et al.'s (2000) practical inquiry content analysis model to determine the extent outcomes of the group inquiry-based SA activities supported cognitive presence. I established that Arleno supported a teaching process that required minimal direct instruction and sustained high levels of cognitive presence.

Across the DBRC1 and DBRC2 interventions, nine group inquiry-based SA activities were facilitated over nine separate weeks, generating 50 answers in total. The categorisation of each answer, according to Garrison et al.'s (2000) practical inquiry model, revealed high levels of cognitive presence in the answers. According to Garrison, text-based outcomes categorised as either integration or resolution represent high levels of practical inquiry which in turn supports cognitive presence. For DBRC1, 44% of the answers were categorised as resolution and 40% integration; for DBRC2, 23.71% of the answers were categorised as resolution and 50% integration. A recent meta analysis combining 30 studies between 2000 and 2019 showed that the mean distribution across the practical inquiry phases was exploration (44%), integration (29%) and the minority of text-based outcomes categorised as resolution (8%) (Sadaf et al., 2021). As such, the results indicate that the outcomes of the group inquiry-based SA activities demonstrate notably higher levels of resolution and integration than most recent studies.

The high levels of cognitive presence achieved across the interventions may be a result of the design choice to develop the group inquiry-based SA activities, supported by Arleno, to scaffold Garrison et al.'s (1999) practical inquiry process. The activities require the teacher to enter an inquiry-focused question related to the annotated content. Students, in their groups, discuss the question, and a single group member is nominated to answer. While exploration will be taking place, in terms of the textual outcomes captured, there is little scope for lower, exploration levels, of practical inquiry.

Wider studies have also reported success with a structured approach (Yeh et al., 2017; Gayoso-Cabada et al., 2019; Shin et al., 2018; Zarzour and Sellami, 2017; Oriogun, 2009). However, the approaches required learners to follow a fixed framework. For example, Yeh et al. (2017) only allowed students, using annotation, to reject or accept arguments made in readings. Oriogun (2009) took an approach that required categorising all messages into one of four categories: "question, unclassified, answer, and delivery" (p. 35). The pedagogical design supported by Arleno allows a balance between rigidity and a free-flowing discussion.

To add further insights into the design choices that led to high levels of cognitive presence, field notes were used to construct a narrative surrounding the group inquiry-based SA activities. The narrative revealed three notable observations regarding how pedagogic design affects inquiry. First, controversy and division led to high levels of participation. Second, activities based around practical learning outcomes with readily available solutions can lead to easily attainable resolution levels of practical inquiry. Third, an activities' success should not necessarily be measured in terms of reaching, the highest, resolution levels of inquiry. Below, in closing my exploration of cognitive presence, I explore each of these observations.

The outcomes of two of the nine group inquiry-based SA activities suggest that controversy and division can lead to high levels of participation. In the DBRC1 intervention an activity was attached to a section of course content that presented a divisive argument surrounding database design. For the DBRC2 intervention, an activity was attached to a paper reporting on a study where Harvard researchers and Facebook, without gaining informed consent, collaborated

to manipulate users' news feeds by regulating positive or negative posts (see Kramer et al., 2014). Both activities generated notably high numbers of answers and supported lively class-wide discussions. A similar outcome was observed in a study by Cesareni et al. (2015) where scaffolding was used to create division in an online discussion environment. The authors noted that structuring discussion in this way led to high levels of participation and student satisfaction. Similarly, Dillenbourg and Jermann (2010) also observed that using opposing opinions to facilitate online discussion is a teaching method that, according to the authors, "works well". As such, it appears, where possible, basing inquiry on topics where opposing views can be debated, compared, and contrasted can facilitate high levels of participation and is a useful teaching tool.

When considering the levels of practical inquiry at an intervention level, it can be observed that practical learning outcomes that lend to readily available solutions can lead to easily attainable resolution levels of practical inquiry. For instance, the DBRC1 intervention, focused on a practical programming module, supported significantly higher levels of resolution levels of inquiry than the theoretically focused DBRC2 research methods module (44% vs 23.71%). The practical nature of the DBRC1 intervention meant that the group inquiry-based SA activities could be focused on questions that guided participants towards real-world solutions. The construction of real-world solutions is an indicator that the highest resolution level of practical inquiry has been achieved (Garrison et al., 2000). A study by Sadaf and Olesova (2017) also showed that questions can be constructed to guide students to resolution levels of practical inquiry. However, Richardson and Ice (2010) remarked that high levels of practical inquiry should not always be the primary goal, as meaningful learning can still take place at lower levels of practical inquiry. Indeed, there is no further evidence to suggest that the second intervention supported a less valuable overall learning experience than the first. As such, levels of practical inquiry should not be the sole metric to measure the success of the overall learning experience.

7.3 RQ3: How did the educational affordances of Arleno's design support teaching presence in terms of the design, facilitation, and direct instruction of the group inquiry-based SA activities?

Above, I established that the group inquiry-based SA activities, facilitated by Arleno, sustained high levels of cognitive presence. I now turn to question three and consider, through exploring teaching presence, the pedagogical affordances that enabled high levels of cognitive presence. Garrison et al. (2001) breaks teaching presence into three sub-functions: direct instruction, facilitation, and design. To address this question, I consider these sub-functions in the context of the two interventions.

Design accounts for the construction of the overall educational experience. According, to Vaughan et al. (2013) the challenge is:

> "How do we design an educational experience that combines the potential for asynchronous online and synchronous face-to-face discourse in a reflective manner that provides the time to think deeply and not speed over enormous amounts of content?" (p. 20).

The use of Arleno allowed the above challenge proposed by Vaughan et al. to be addressed through two notable affordances. First, the tool allowed text-based learning materials to be presented to learners in an organised and discoverable way. Second, the group inquiry-based SA activities, attached to key sections of the material, prompted learners to slow down, take note, and engage. As such, this study has shown how group inquiry-based SA activities, facilitated by Arleno, solved the design challenge of engaging students in text-based learning materials.

Moving on from design, direct instruction and facilitation are interlinked and will be considered together. To recap, according to Vaughan et al. (2013), it is the role of direct instruction to ensure that discourse is "purposeful, rigorous, and productive" (p. 65). Direct instruction ensures a smooth facilitation and allows social presence to emerge; in turn, cognitive presence is then supported. While direct instruction and facilitation are interlinked, Garrison et al. (1999) recommends direct instruction be kept to a minimum and be the domain of the instructor. Conversely, any member of the learning community can facilitate.

Regarding the group inquiry-based SA activities conducted across the interventions, a notable observation was that minimal direct instruction sustained high levels of cognitive presence. This outcome contrasts with wider studies showing that often instructors play an overactive role to sustain an online learning community (Friess and Lam, 2018; Liu et al., 2018). For example, Liu et al. (2018) reported, regarding the running of an online course, that instructor posted content accounted for over a third of the 304 postings. In contrast, the findings from this study show that only 16% and 14% of the SA activity textual outcomes were instructor created across the first and second interventions respectively. Usually, only the trigger question was provided by the instructor, with learners providing the answers. As such, the activities supported by Arleno align to Garrison et al.'s (1999) advice of maintaining low levels of direct instruction.

7.4 RQ4: What were students' historic perceptions towards text-based learning materials and group work; and, in terms of text-based learning materials, how did the interventions change these perceptions?

To this point, the research questions have focused on the outcomes of the interventions in terms of the cognitive presence supported and the pedagogical concerns that led to these outcomes. Question four marks a change of perspective to that of the intervention participants. Across the two interventions, participants worked in small groups to take part in SA activities intended to engage them in text-based learning materials. The above question, answered through semi-structured interviews, is designed to further understand the intervention participants' historic attitudes towards group work and text-based learning materials. Further to this, in terms of attitudes towards text-based learning materials, the perceived effect of the interventions was explored.

Regarding group work, participants brought conflicting values into the interventions. They valued the theoretical learning opportunities a group setting can provide. However, in practice, the group dynamic is rarely functional to the extent that meaningful learning can take place. As such, the anticipation of a non-functional group can give rise to strong emotions such as dread and fear. Aligned with the observations of wider studies, further heightening anxiety is the

prospect of the group setting being online (Ragusa, 2017; Brooks and Young, 2016). In an online setting, participants felt group members had less accountability and could hide behind a turned off camera. Broadly, the participants' attitudes towards group work echo the outcomes of a thematic synthesis conducted by Caskurlu et al. (2021). In this study, the authors evaluated 35 studies that used Garrison et al.'s (1999) CoI framework to guide group inquiry in a HE setting. They found students showed a preference towards individual work due to their historic experiences of variable group dynamics. Overall, these attitudes presented barriers that the collaborative nature of the group-focused learning solution had to overcome.

Turning to participants' historic experiences of text-based learning materials, the interview outcomes suggested there had been little historic engagement. The participants are second-year computing students at a teaching intensive university. While courses have reading lists and text-based materials, there has been little, historic, need to engage. Similar to reports from wider studies exploring reading engagement in HE (Baier et al., 2011; Berry et al., 2010), participants reported receiving high grades, despite not engaging with or citing text-based learning materials. Their attitudes aligned to the profile of what Biggs (1999) describes as "non-academic" students. According to Biggs, unless the "most favourable teaching conditions" are created "non-academic" students will assume Marton and Säljö's (1976) idea of a surface-level approach to learning materials. Such an idea aligns well to the participants historic experiences with text-based learning materials.

Above, I established that the intervention participants broadly fitted Biggs's (1999) definition of "non-academic" students. Biggs suggests the reason that such students do not engage in learning materials is lack of intrinsic motivation to learn. However, in the context of this current study, I found this not to be the case. A single student noted lack of motivation to engage in text-based learning materials; this attitude, however, did not represent the majority. It appears that time constraints arising from the need to undertake paid work present a more prevalent barrier. This conflict between paid and university work was also observed in the results of a survey conducted on 185 first-year Australian

computing students (Sheard et al., 2010). The outcomes revealed that students undertook an average of six hours paid work a week and 18% worked more than 15-hours a week. For many students this work is not optional. A study involving 77 first-year students attending a British university revealed that 45% of respondents expected to encounter financial struggles (Hassel and Ridout, 2018). Overall, the idea suggesting that students are not intrinsically motivated is an oversimplification. Rather, commitments, external to their studies, may prevent them from having the time to explore learning materials in a more academic way.

Above, I argued the outcomes of the interviews established that the intervention participants were "non-academic" students and, before the interventions, had experienced little meaningful engagement with group work or text-based learning materials. Therefore, the most striking outcome of the interventions was that participants reported increased motivation to engage in text-based learning materials and overall criticality. Furthermore, they started to develop systems to apply their newfound levels of criticality. In terms of the increase in motivation, these outcomes align with studies showing that SA activities motivate engagement with text-based learning materials (Miller et al., 2018; Vorobel et al., 2018; Zarzour and Sellami, 2017; Chen and Su, 2019). However, aligning SA activities with Garrison et al.'s (1999) inquiry process to support a CoI has wider-reaching outcomes. Applying a CoI in this context can enhance engagement and critical thinking abilities, which is what a functioning CoI should do. However, according to Garrison et al.'s (2001), guiding learners past the lower levels of inquiry to support critical thinking is a challenging undertaking. As such, the collaborative, socially situated nature of the group inquiry-based SA activities are well placed to support a CoI.

7.5 RQ5: What were students' perceptions and experiences of using Arleno in terms of the group inquiry-based SA process followed, the social presence supported, and the usability?

Answering the above question framed an exploration into the participants' perceptions of the learning solution underpinned by Arleno. The question explores three different perspectives: usability, social presence, and group process followed.

In addressing this question, I will consider each of these perspectives.

7.5.1 Usability

Participants reported that Arleno was easy to access, use, and organised text-based learning materials in a discoverable way. This positions Arleno as a usable alternative to existing text-based discussion environments commonly used. The traditional domain for hosting text-based learning activities has been the LMS discussion board. However, studies have reported that discussion boards are hard to access and use (Gronseth and Hebert, 2019; Harris, 2017). As a result, there has been a trend of teachers turning to for-profit, social messaging applications and tools (O'Dell, 2020; Davis, 2010; Tuhkala and Kärkkäinen, 2018; O'Dell, 2020). However, doing so, raises concerns surrounding privacy and data ownership. Arleno is open source, and the learners' data belongs to the institution not a for-profit company. As such, Arleno can offer a secure and usable alternative to the traditional LMS discussion board.

A further implementation detail of note is the design choice of placing annotation outcomes in a pop-over window. The interviews revealed that participants found this feature an effective and focused way of managing a discussion point. Further to this, the group inquiry-based activities conducted within this digital space supported high levels of cognitive presence (Garrison et al., 2001). The use of a pop-over challenged the design of most SA tools that take inspiration from traditional pen and paper annotations (Miller et al., 2016; Zyto et al., 2012). In doing so, they display annotation outcomes in a virtual margin. However, given the space constraints, a margin has been shown to limit the discussion depth (Chen and Yen, 2013). As such, the outcomes of this study agree with Chen and Yen's (2013) conclusions that a pop-over window can act as a compromise between the confines of margin annotations and the affordance of being able to construct longer answers, normally only supported by traditional discussion boards.

7.5.2 Social Presence

For Garrison et al. (1999), social presence is the level to which students can project themselves onto the learning environment in an authentic way. Kirschner et al. (2004) ideas surrounding social affordances further operationalise this idea by arguing online learning environments must offer perception action coupling. Perception action coupling is the concept that once a learner enters a learning environment; this environment encourages and guides social interaction. Arleno was designed to offer perception action coupling through three features:

- the ability for a learner to upvote their peers' group inquiry-based SA activity answers.
- the ability for a learner, through the social presence detector, to project their profile pictures over the content they are reading.
- the ability for a learner, through answering the SA inquiry-based activities, to project themselves onto the text-based learning material.

The ability to upvote answers is a feature, inspired by modern social web applications, intended to allow the affordance to easily show appreciation towards the outcomes of the group inquiry-based SA activities. Upvoting has been successful in less structured online communities (Potts and Harrison, 2013); however, the feature did not serve its intended affordance when applied to an inquiry-based SA activity. Rather than showing appreciation, participants felt that an upvote suggests agreement. Further, there was a feeling that upvotes could be manipulated (e.g., friends could upvote each other), cause learners to feel anxious about not achieving any votes, and there was also sentiment that some learners may feel anxious about not achieving any vote. The outcomes contradict the findings of a study by Wijenayake et al. (2021) that tested an upvoting feature on a researcher created debating application, used by 48 students for a week. Interview outcomes revealed that participants found the ability to vote on messages a welcome and easy way to interact with fellow learners. These contradicting outcomes could be attributed to the additional functionality of downvoting, whereas Arleno only allows upvotes. As such, an interesting development would be to test a wider range of answer interactions.

Like upvoting, the presence detector is also inspired by modern social web applications. The feature projects the learners profile pictures over the content they are reading. In contrast to the upvoting feature, the presence detector was well received. It connected learners with fellow readers, fostering a sense of togetherness. The idea of group awareness can go some way in explaining the success of this feature (Bodemer and Dehler, 2011). Group awareness is the extent that group members are aware of each other's presence in the online learning setting. In considering the types of group awareness offered in a learning environment, Buder (2011) draws the distinction between features that support group awareness as implicit and explicit. As such, the presence detector is a feature that implicitly supports group awareness, allowing learners to project their presence onto the learning environment with little to no effort.

Above, I established that the presence detector implicitly supports group awareness. The features allowing a learner and teacher, through engaging the SA inquiry-based activities, to project themselves onto the text-based learning material supports explicit group awareness. The annotation question enables the teacher to announce to the learning community that the annotated content is important and requires further consideration. In answering the question, learners share their thoughts with the teacher and their peers. The idea that SA allows access to an otherwise opaque process of thinking is a common outcome noted in studies using SA in the learning setting (Kalir et al., 2020; Clapp et al., 2021; Vorobel et al., 2018). For instance, Clapp et al. (2021) discovered that students find reading other peoples' annotations more helpful than writing their own. Students explained that looking at third-party thought processes aided individual understanding. Further, both Kalir et al. (2020) and Clapp et al. (2021) discovered that students found SA as a way to express themselves more freely than traditional face-to-face discussions. In summary, the process of SA allows the learning community a means to project their presence onto text-based learning materials in a way that would otherwise not be possible with traditional static learning materials.

7.5.3 Group Process Followed

To recap, based on the interview outcomes with participants, four approaches to completing the group inquiry-based SA activities were established: "gather and compare", "delegation", "free flowing discussion", and "a job to be done". The former three approaches aligned to Garrison et al.'s (1999) inquiry process where ideas are externalised and discussed. However, the final approach identified, "a job to be done", is in opposition to Garrison et al. (1999)'s ideas surrounding productive inquiry. This method involved learners completing the task as quickly as possible and avoiding any meaningful discussion. What follows is a brief exploration of these approaches in the context of wider studies.

"A job to be done" is an undesirable approach where students see the activity as just another job to get done as quickly as possible. It may be caused by tensions arising from students' individual goals not aligning with collective inquiry values. For instance, studies have noted that if students are grade focused, they may not see value in group-based learning (Molinillo et al., 2018; Liu et al., 2018). As such, in the words of Davies (2009), there is a "social dilemma" resulting in high levels of self-interest and a disregard of group outcomes. Further contributing to this social dilemma are observations that SA exercises can increase the cognitive load of engaging with what may already be complex text-based learning materials (Kalir et al., 2020; O'Dell, 2020; Clapp et al., 2021). Overall, participants following "the job to be done approach" may have been reluctant to take onboard a cognitively demanding task representing no individual grade value.

As established above, the remaining group strategies followed, "gather and compare", "delegation" and "free flowing discussion", aligned to Garrison et al.'s (1999) inquiry process. "Gather and compare" is a technique involving group members working individually on an answer and then coming together to form a collective answer. "Delegation" splits the SA task into sections that can be delegated. "Free flowing discussion", the most popular strategy, involves learners engaging in group-wide, free-flowing discussion to answer the inquiry-based question. These approaches require student groups to stop, think, and discuss key sections of the text-based learning materials. In other words, they must take a deep-level approach towards engaging with the learning materials (Marton and

Säljö, 1976). This finding aligns with wider studies suggesting SA and CMC can increase learner motivation to engage with text-based materials (Vorobel et al., 2018; Miller et al., 2016; Zarzour and Sellami, 2017; Chen and Su, 2019). Overall, from the perspective of my study, groups adopting these approaches meet the aim of encouraging students to engage in a deep and meaningful way with text-based learning materials.

Barriers Preventing Deep Learning

As discussed above, the participants described a group-inquiry process that, on the whole, is conducive to a critical CoI. However, as with any learning activity, there were also reports of barriers at odds with the productive approaches. Primarily, these barriers are related to one or more group members not participating. This was a result of students being unable to navigate a group dynamic and an over-reliance on individuals others know will do the work for them. In the worst case, this could cause a complete breakdown in social presence, and what I called a "stand-off" could occur. This is where a group sits silently in the online breakout rooms, sometimes for extended periods. This shows the importance of the social presence component of a CoI (Garrison et al., 2001); without it, a functioning CoI cannot form.

Above, we have seen that, in the worst case, a breakdown in social presence can cause a stand-off. This was primarily a symptom of the DBRC1 intervention's activity design choice of assigning students to random groups on an activity-by-activity basis. Students had to reconcile a new group dynamic for each group inquiry-based SA activity, and there were times social presence could not form. It is perhaps because of this observation that Davies (2009) recommends that groups are "of longer-term, rather than shorter-term duration" (p. 575). Changing the activity design for DBRC2, allowing learners to choose their groups, solved the problem of stand-off. However, partial participation remained an issue. Partial participation is where one or more group members are present but choose not to participate in a meaningful way. This form of disengagement is a common observation of group work in a learning setting (Buder, 2011; Davies, 2009; Kreijns et al., 2003). Common terms used to describe this observation, coined by Strong

and Anderson (1990) are "free-riding" and "suckers". This is where inactive group members "free ride" on active group members' work. According to Strong and Anderson, as the interviews showed, this leads to the active participants feeling like "suckers", resenting doing the work for other people and eventually starting to withhold their input.

As established above, partial participation is a prevalent, perhaps an unavoidable, problem of CMC facilitated group activities. Interestingly, Kreijns et al. (2003) note that activities overly focused on cognitive outcomes can contribute to partial participation. The group inquiry-based SA activities, scaffolding Garrison et al.'s (1999) ideas around cognitive presence, may fit the category of being overly focused on cognitive outcomes. For Kreijns et al. (2003), there may be instances where such activities do not allow the right kind of social presence to form.

According to Buder (2011), a solution to partial participation may lie in raising the levels of group awareness in the CMC setting. Buder suggests that "perceiving and knowing that others have contributed more than oneself is likely to activate some degree of normative pressure, thereby preventing free-riding from taking place" (p. 116). Bodemer and Dehler's (2011) work, building on Buder's (2011) ideas, provides a means to explore how to increase group awareness within Areleno. Bodemer and Dehler (2011) categorises group awareness into behavioural, the level an online environment informs learners about the actions of their peers; cognitive, the degree to which knowledge can be shared; and social, the extent an online environment allows collaboration. In considering these awarenesses, I established above that Arelno offers high levels of social awareness. Further, engaging in SA allows learners to share constructed knowledge and achieve cognitive awareness. However, the activity design only required a single group member to answer the inquiry-focused activity questions. As such, there was little in the way of behavioural awareness concerning the other group participants. Overall, the solution could lie in increasing behavioural awareness among the remaining group members. For instance, a leader-board based on interactions with fellow groups' answers.

7.6 A Critique of the CoI's Connection to Deep-Level Engagement

In this chapter, I have addressed each of the study's research questions. In doing so, I have explored all three CoI presences necessary to support deep-level engagement across the two interventions: cognitive, social, and teaching (Garrison et al., 1999). According to the model, the aspirational learning experience neatly exists in the intersection of all three presences. However, I found it hard to rationalise how the interplay of the three core elements affected the overall learning experience. While Garrison et al. places equal importance on all presences, cognitive presence allows researchers to evaluate, through textual analysis of the online discourse, the extent a CoI has supported deep-level engagement. As such, many studies turn to this type of analysis to determine the success of a given learning design or intervention (see Sadaf et al., 2021). I, however, found basing the success of a CoI on textual analysis alone could be misleading. Notably, the second intervention, demonstrating lower levels of cognitive presence than the first, should have been a less efficient CoI; however, there was evidence of learner-reported productive inquiry and high levels of social presence across both interventions. Overall, this suggests that the widely used approach of transcript analysis as an indicator of success may be a narrow interpretation of the CoI and fail to capture deep-level engagement.

Above, I established that studies often use transcript analysis of the online discussion environment to gauge the level of success of a CoI. However, evaluating the CoI through this objectivist lens is a troublesome interpretation of Garrison et al.'s (1999) framework for four reasons. First, online discussion transcripts only represent a small cross-section of the overall learning experience. Second, there is little evidence that a co between presences exists, with reviews of the literature showing no connection between presences and deep-level engagement (Rourke and Kanuka, 2009; Annand, 2011). Third, according to Garrison (2005), a deep approach to learning must consider "all three elements of the community of inquiry" (p. 144). Finally, the creators of the CoI, state that the framework supports "how we construct knowledge as opposed to an objectivist focus" Akyol et al. (2009, p. 124). These ideas suggest the CoI's utility lies beyond its common objectivist interpretation. Rather, as Garrison et al.'s (2001) states, it is the

"responsibility of a teacher" to judge the quality of deep-level learning on a context-by-context-basis (p. 8). Therefore, by using a mixed-methods approach that focused on both the learning process and cognitive outcomes supported in my direct learning setting, I have addressed the challenges of applying the CoI through an objectivist lens.

7.7 Design Principles

This final section brings the discussion to a close by presenting design principles derived from the overarching DBR project. The goal is to allow the learning and outcomes of the project to apply to wider learning settings (Reeves, 2006). According to Van den Akker (1999), design principles should consider:

> "If you want to design intervention X [for the purpose/function Y in context Z], then you are best advised to give that intervention the characteristics A, B, and C [substantive emphasis], and to do that via procedures K, L, and M [procedural emphasis], because of arguments P, Q, and R. (p. 5)"

Van den Akker's (1999) ideas suggest that design principles should focus on the creation and use of the solution. The solution created for this project is Arleno, an open-source tool that supports HE students in adopting what Marton and Säljö (1976) refer to as a deep-level approach towards engaging in text-based learning materials through group inquiry-based SA activities (Marton and Säljö, 1976). In creating this solution, I took the rare approach of assuming the roles of programmer, researcher, and teacher to design, implement, and test the learning solution myself. As such, I present design principles from two perspectives: first, from that of an individual looking to develop a tool to solve some identified problem in the learning setting; second, from that of a teacher or researcher looking to use Arleno in their teaching setting.

7.7.1 Development Considerations

What follows is the first, of two sets, of design principles. As mentioned above, I begin by considering concerns surrounding the design and development of learning

solutions. These principles provide practical guidance to support individuals or teams interested in developing tools to solve problems identified in the learning setting.

Gradually Decrease the Levels of Theoretical Abstraction

Walker (2006) identifies the challenge of DBR is to design a system "based on theories and determine the effectiveness of these systems in practice" (p. 11). An effective approach is through gradually decreasing the levels of theoretical abstraction. I started with my commitment to a socio-constructivist approach to learning. Garrison et al.'s (1999) CoI guided how to operationalise this approach in a text-based learning setting. Finally, I used ideas inspired by studies exploring SA and CMC to design a tentative solution. Overall, this saw me go from the abstract to a concrete, testable implementation.

Construction Will Take More Time Than Expected

This principle serves as a cautionary point. In the case of this project, the two design and construction phases overran. To ensure the learning tool could be tested, I had to sacrifice functionality. A team size of one undoubtedly delayed the development cycles. However, regardless of the team size, I recommend the first version of a learning solution be treated as a proof of concept, with just enough functionality to allow it to be tested in the learning setting.

Extend DBR With an Agile Design Thinking Approach

DBR requires design propositions to be mapped to a concrete solution solving a problem identified in the learning setting. An approach is to extend DBR with agile design thinking (Pereira and Russo, 2018). McKenney and Reeves (2012) suggest that the functionality of a given solution should gradually increase over time, and an agile design thinking approach is well suited to this idea. They advocate working closely with stakeholders to develop and test rapid prototypes to solve an identified real-world problem. Early prototypes do not have to be functional; for instance, I showed a solution in the form of rough mock-ups when interviewing fellow teaching practitioners in the early phases of the DBR project.

Overall, extending DBR with agile design thinking allows design propositions to be validated early in the design process.

Consider Using User Stories

A learning solution involves testing design propositions in the learning setting (McKenney and Reeves, 2012). Representing design propositions as user stories can assist this process. User stories are a design tool used in agile software development (Cohn, 2004). A story captures how a specific user interacts with a small part of the intended solution. Taking this approach allows the stories to be prioritised and implemented in order of priority. As such, the stories mapped to the most important design propositions are implemented and tested first.

Develop Using Components

According to McKenney and Reeves (2012), "prototype components gradually transition from temporary versions to more enduring ones" (p. 126). Aligning to this idea, I recommend taking the programming approach of developing the parts of the prototype as stand-alone components. This approach allowed Arleno to be easily and quickly reconfigured based on learners' and stakeholders' feedback. I gradually rolled out new components even when the intervention was in progress. Overall, this approach allowed for the continuous evolvement and improvement of the learning tool.

7.7.2 Teaching Considerations

I now consider design principles surrounding using Arleno in a learning setting. Insights from using Arleno across two semester-length interventions to support group inquiry-based SA activities form the basis of these recommendations. These principles guide researchers and teaching practitioners looking to use SA to support HE, undergraduate students in taking a deep-level approach towards engaging in text-based learning materials.

Use Synchronous Activities

When working with undergraduate students, I recommend using synchronous SA activities. Planning the activity is simply the case of attaching an annotation to an excerpt of text in the learning material and proposing an inquiry-based question. I recommend breaking students into small groups to complete the activity. A single student should answer on behalf of the group. Overall, this process supported high levels of practical inquiry and student satisfaction.

Allow Groups to Form Over the Long Term

The SA activities facilitated by Arleno scaffold Garrison et al.'s (1999) practical inquiry process. Practical inquiry is group-based, and teachers should carefully consider the group formation strategy: I experimented with two. For the first intervention, I randomly assigned students to groups on an activity-by-activity basis. However, forming groups in this way required group members to reconcile the group dynamic for each task before starting the inquiry process. The reconciliation process was time-consuming, and worst case could result in a stand-off where participants would not speak for extended periods. For the second intervention, learners self-selected their groups, remaining in them for the entirety of the semester. This allowed for Garrison et al.'s (1999) ideas surrounding social presence to form gradually. Further, learners would only have to reconcile the group dynamic once. As such, I recommend that inquiry groups should be allowed to form over time.

Know When to Use Direct Instruction

In line with Garrison et al. (1999) light touch suggestions towards direct instruction, I intentionally stayed away from the online-breakout rooms facilitating the group inquiry-based activities. However, the post-intervention interviews revealed some facilitation issues relating to partial participation and general disinterest in collaborative work. While I am still an advocate of a light-touch approach, I recommend that instructors monitor activity outcomes for indicators such as tasks completed quickly or not at all. The instructor can then apply direct instruction to mediate solutions.

Do Not be Overly Focused on Cognitive Outcomes

I evaluated the group inquiry-based SA activities, supported by Arleno, through two interventions: DBRC1 and DBRC2. The DBRC1 intervention focused on a practical programming module and sustained higher levels of cognitive presence than DBRC2, which focused on a theoretical module. However, both interventions supported a productive CoI, which honed learners' criticality and engagement with text-based learning materials.

Based on the above observation, I recommend that a teacher not be overly focused on achieving the highest resolution levels of cognitive presence (Garrison et al., 2001). Indeed, Kreijns et al. (2003) note that activities tightly focused on cognitive outcomes can contribute to partial participation. In other words, if the SA activity is too cognitively demanding, some learners may not be willing to take part.

7.8 Conclusion

This chapter has placed the findings in the context of wider studies and theories. I began by considering the complexities of designing, developing, and testing a learning solution based on a newly developed web-based tool. I reflected on how it was necessary to bring together the roles of programmer, teacher, and researcher. Central to this process is the idea of progressing through decreasing levels of theoretical abstraction. I started with a socio-constructivist position and then moved to more practical ideas such as the CoI to guide the design (Vygotsky, 1980; Garrison et al., 1999; Meyer and Land, 2005). Finally, I demonstrated how I combined an agile design thinking approach with DBR to manage the process of translating theory into concrete implementation. Overall, I have presented a framework to create learning tools.

The design process resulted in a new learning tool, Arleno, reported by learners to be usable and accessible. It supported a pedagogic design underpinned by group inquiry-based SA activities. I established that the participants engaging in the activities are non-academic students (Biggs, 1999). They had little prior experience of productive group inquiry or engagement with text-based learning

materials. Nonetheless, the SA activities demonstrated outcomes that achieved notably high levels of cognitive presence. I credited this success to the structured annotation approach, and the design features of Arleno that allow high levels of group awareness to be established (Sadaf and Olesova, 2017). In essence, the process of SA allows learners and teachers to capture, alongside the content, a thought process that may be lost or invisible.

In closing, I presented design principles guiding an individual or team looking to develop a new tool to solve identified problems in the learning settings. The design principles represent actionable advice based on reflections from a three-year DBR project, spanning pedagogic and technical aspects of learning solution design and use. They capture perspectives from the multiple roles I assumed (programmer, teacher, and researcher) for the project. As such, the principles are of use to an individual or team looking to use the Arleno; or, those looking to develop their own learning solutions.

Chapter 8: Conclusion

What follows are my concluding thoughts on a three-year DBR study. My motivation to conduct the study stemmed from observations in my practice setting, where I work as a computing lecturer, in a teaching-intensive UK-based university. I observed my students were not engaging in text-based learning materials. Interviews with the teaching community, within my university, revealed the problem is institution wide. Furthermore, there is evidence to suggest only a minority of HE students engage with text-based learning materials (Starcher and Proffitt, 2011), and it is an unsolved, growing problem (Starcher and Proffitt, 2011; Baier et al., 2011). As such, lack of engagement in text-based learning materials is an unsolved problem spanning the HE sector.

To frame the study's aim, I used Marton and Säljö's (1976) distinction between a surface- and deep-level approach towards engaging with text-based materials. A deep-level approach involves engaging with content critically and forming connections between the content and wider ideas. Such an approach develops a learner's critical thinking abilities. Conversely, a surface-level approach is where the content is accepted at face value. With these definitions in mind, developing a solution that could support students in taking a deep-level approach towards engaging in text-based learning materials formed the study's aim.

I approached the study's aim by combining my experiences as a researcher, teacher, and programmer. In doing so, I constructed a theoretical framework based on Garrison et al.'s (1999) CoI that guided the development of a new learning tool called Arleno, a SA inspired CMC. The tool engages students in text-based learning materials by allowing group inquiry-based SA exercises to be attached to the material. The SA activities are structured, guiding learners through Garrison et al.'s (1999) stages of practical inquiry required to support cognitive presence in a CoI. The learning tool supported two 12-week interventions with 50 and 75

participants taking second-year synchronous modules in database programming and research methods. Across the interventions, Arleno hosted the modules' content and nine group inquiry-based SA activities that generated 50 total answers.

The group inquiry-based SA activities ran synchronously within online seminar sessions. Before these sessions, as the teacher facilitating the learning, I annotated the text-based learning materials with a single group inquiry-based SA activity. Each activity, attached to a section of the modules' text-based content, centred around a teacher-created inquiry question. Within the seminars, learners discussed and answered the question in small groups of five, with a single group member entering the collaboratively constructed answer. A pop-over window overlaying the text-based content facilitates the activities. Such a design choice challenged the traditional in-margin space used to facilitate annotation activities, limiting the size of the activity area. Overall, the design choice facilitated the anchoring of an inquiry process to ideas represented in the learning material and allowed for focused discussion across the nine group inquiry-based activities run across the two interventions.

I evaluated the interventions through the quantitative content analysis of the 50 activity answers, 24 semi-structured interviews (12 after each intervention), and analysing my researcher and programmer field notes to answer the following research primary question:

What are the learning opportunities, benefits, and challenges of developing an open-source learning tool, named Arleno, to engage HE students in taking a deep-level approach towards text-based learning materials through group inquiry-based social annotation activities supporting a Community of Inquiry?

The above research question captured the theoretical, empirical, and practical impulses of the study. I answered it by assuming the roles of a teacher, researcher, and programmer. In bringing these roles together, I progressed through decreasing levels of abstraction from a theoretical position based on Vygotsky's (1980) socio constructivism; to the concrete implementation and real-world use of the open-source learning tool Arleno. The tool was challenging to develop, with both design and construction cycles overrunning; however, it was well-received by

learners. The interviews revealed that the intervention participants found Arleno to have the affordances of organising learning materials and annotation exercises attached to these materials in a usable and accessible way. I credited these observed levels of usability to the use of the agile, design thinking development approach taken (Pereira and Russo, 2018). Such an approach allowed me to incrementally add high-quality components of functionality to the solution. Overall, the result was a modern, usable learning tool that effectively supported learners in conducting group inquiry-based SA activities.

The outcomes of performing content analysis on the 50 SA activity answers, conducted across the two 12-week interventions, revealed high levels of cognitive presence (Garrison et al., 1999); this indicates that a deep-level approach towards engaging in text-based learning materials was taken. Further to this, the participants, having had little meaningful historic exposure to group or text-based learning, reported increased levels of motivation and criticality. As such, the interventions broadly addressed the study's aim of supporting students in taking a deep-level approach towards engaging in text-based learning materials. Overall, I attributed the high levels of practical inquiry to the affordances of Arleno that allowed a structured annotation approach to be taken that foster high levels of cognitive presence.

Turning to the learners' voice, the outcomes of the participant interviews led me to conclude that Arleno supports high levels of social presence (Garrison et al., 1999). I credited the levels of social presence to Areleno's design incorporating features supporting group awareness (Bodemer and Dehler, 2011); in particular, the social presence detector and the SA process. Through a social presence detector, learners' profile pictures are projected over the text-based content they are reading. Further to this, through using Arleno to engage in SA activities, a type of group awareness known as cognitive awareness is supported (Bodemer and Dehler, 2011). Cognitive awareness allows constructed knowledge to be presented to fellow learners, and the process of SA proved an effective way to project collaborative knowledge onto text-based learning materials. Overall, Arleno, and the group inquiry-based SA activities it supports, transforms the normally individualistic endeavour of consuming text-based materials into a social

undertaking.

Finally, in considering the teaching presence (Garrison et al., 1999), there were two findings of note. First, from an instructional perspective, minimal orientation with Arleno and the SA activities it supported were required. However, despite the low levels of direct instruction, intervention participants reported that, in unsupervised breakout rooms, they largely followed one of three productive inquiry approaches: "gather and compare", "delegation", and "free-flowing discussion". Second, Arleno allows a large amount of text-based content to be presented to learners in an organised way. Crucially, however, the affordance of being able to attach SA activities to this content ensures that learners slow down and engage deeply. As such, enabling the study's aim to be achieved, and solving a fundamental design challenge defined by Vaughan et al. (2013) of supporting learners to "think deeply and not speed over enormous amounts of content" (p. 20).

8.1 Study Contributions

This study addressed the aim of designing a solution to support HE students in taking a deep-level approach towards engaging in text-based learning materials. In achieving the aim, I assumed the rarely combined roles of researcher, programmer, and teacher to construct and refine, through two DBR interventions, a web-based learning tool. Bringing together these distinct roles led to empirical, theoretical, and practical contributions.

First, I have shown how a theoretical framework, based on social constructivism and operationalised through the CoI, can guide the design, implementation, and evaluation of a digital learning solution. In doing so, I have developed the CoI theory in terms of its application in the unique context of constructing a digital tool to support computing students to take a deep-level approach toward engaging with text-based learning materials. I used developer and researcher logs to provide rich reflective accounts of this process; this allowed me to demonstrate how to use sound learning theory to guide the construction of a digital learning solution. In summary, I have provided a blueprint that a cross-disciplinary team or individual can use to create learning solutions.

Second, I made concrete contributions to the CoI's cognitive, social, and teaching presences. I showed how group inquiry-based SA activities, supported by Arleno, can sustain high levels of cognitive presence. From the perspective of teaching presence, activities provided an intuitive experience for learners and teachers, needing minimal orientation and direct instruction. In terms of social presence, I showed how the process of SA can allow access to an otherwise opaque thought process. Furthermore, I demonstrated that SA allows the learning community to project their presence onto text-based content. These ideas will be helpful to researchers, learning designers, and teachers looking to use the CoI to support online, collaborative learning.

Third, the use of semi-structured interviews as the primary method addressed the lack of in-depth qualitative inquiry exploring CMC tool use in the learning setting. I explored areas such as the group inquiry process followed and participant perceptions. In doing so, I identified tool and learning design features that supported group awareness, social, and cognitive presence. Furthermore, I established group strategies followed along with barriers preventing productive group inquiry. This resulted in the construction of design principles surrounding the learning design of group inquiry to support a CoI and addressed the neglected participant voice surrounding CMC environments. In doing so, I contributed to the lightly explored student voice. The outcomes will be of use to learning designers, teachers, and researchers who wish to design new learning solutions or wish to further develop Arleno.

Fourth, the iterative nature of DBR allowed me to experiment, improve, and validate technical and practical features of the online learning solution. For instance, I designed Arleno to facilitate annotations in a pop-over window. In doing so, I challenged the conventional in-margin annotation design that has become the norm. I established that a pop-over served as a focused space for discussion. As such, I contributed to the limited evidence that, in terms of depth of discussion, pop-over annotations are more effective than the traditional in-margin alternative (Sun and Gao, 2016; Chen and Yen, 2013). Furthermore, I connected participants' perceptions to granular tool design features such as upvoting and presence detection. These features were validated and refined based

on real-world feedback. Finally, I experimented with learning design choices such as group formation strategies. Overall, the empirically validated features and learning designs contribute a foundation to future studies aiming to develop socio-constructivist learning solutions.

Fifth, through two DBR interventions, I validated and documented the process of creating a solution supporting students to take a deep approach towards engaging with text-based learning materials. Drawing on the multiple roles I assumed, I presented design principles covering digital, theoretical, and pedagogic concerns. The principles contribute to the spread of mine and further solutions.

Finally, perhaps the most important contribution is an open-source learning tool called Arleno. My commitment to open-source means Arleno is freely available to use and extend in wider learning settings. Learning institutions can self-host, inspect, and control the data the tool gathers. In allowing these freedoms, I have addressed the data ownership and privacy concerns widely observed with commercial for-profit discussion tools (Davis, 2010; Tuhkala and Kärkkäinen, 2018; O'Dell, 2020). Furthermore, I have answered the call by O'Dell (2020) to guide the creation of modern, learning-focused SA tools. As far as I am aware, this call has gone largely unanswered.

8.2 Study Limitations

This study has utilised my roles as a researcher, programmer, and teacher to analyse data from multiple perspectives. The data ranged from field notes, 24-semi structured interviews, and the content analysis of the 50 answers generated through the nine annotation activities. The data provided valuable insights and design recommendations contributing across theory and practice. However, whilst these insights were novel and addressed the research questions, six limitations should be considered.

First, while the data collected provided a unique perspective, the large size of the data set presented a significant analytical challenge. Such a challenge is commonplace in DBR studies. For instance, McKenney and Reeves (2012) note that one of the concerns of DBR is it "involves massive amounts of data collection" (p. 201). Given the scope of a PhD project, I could only present one

data and results story out of many possible ones. As such, there could be lines of inquiry left unexplored. Overall, I hope to address this limitation through the ongoing nature of a DBR project.

Second, a further challenge resulting from the expansive nature of DBR is I did not have the time or resources to explore students' perspectives of the challenges surrounding engaging in text-based learning materials and a proposed solution to these challenges before conducting the interventions; instead, I had to persue this line of inquiry in the post-intervention interviews. Given the cyclic nature of DBR, the DBRC1 post-intervention interviews supported the DBRC2 intervention; however, the DBRC1 intervention lacked the learners' perspectives.

Third, due to the themes from DBRC1 and DBRC2 emerging to be similar, they were combined and reported in a single chapter. From a reader's perspective, this means that a limitation of the study is the inability to be able to see a comparative perspective between the learner-reported outcomes of the two DBR cycles.

Fourth, completing the project involved me assuming roles of programmer, teacher, and researcher. At times this required compromises to be made in each of these areas. While this is a limitation, the collective perspectives obtained through multiple roles would not have been possible without incurring it. As such, it is arguably a sacrifice worth making.

Fifth, the ongoing Covid-19 pandemic required a rapid transition to online learning. As a result, I had to work to tight time constraints to design tools that could provide an empirical lens on the group inquiry-based SA activities that formed the focus of the interventions. I was able to capture answers to the activities. However, there was no way to objectively determine the inquiry process that produced the answers. Instead, I relied on participants self-reporting the process. Without the ability to triangulate these reports, the accounts of the group process may be subject to misrepresentation or omissions.

Sixth, I was primarily responsible for creating, testing, and evaluating the learning solution. Apart from two weeks, I was the only teacher that used Arleno, and as the creator, I had an intricate knowledge of its workings. As such, I could not determine how easy a teacher not familiar with the project would find the tool

to use. Furthermore, content analysis established that the group inquiry-based SA activities supported high levels of practical inquiry. However, there was no way to validate the findings through inter-coder reliability. Overall, these limitations arise from conducting a project in isolation and could not be avoided.

8.3 Suggestions for Further Research

This project provided significant empirical, theoretical, and practical contributions; nonetheless, the ongoing nature of a DBR project presents opportunities for further research. As such, I bring this thesis to a close by noting some future research recommendations.

First, it would be interesting to further investigate group formation strategies. Group-based learning forms the foundation of socio-constructivist knowledge creation. However, there is little empirical evidence on the best ways to form groups. Across the two interventions, I experimented with two different approaches. For DBRC1, I assigned participants to random groups for each inquiry-based activity. For DBRC2, participants self-selected groups at the start of the semester, remaining in them for the intervention. The findings indicated that these strategies raised different challenges. Assigning random groups could lead to the time-consuming task of navigating a new group dynamic for each activity. Allowing self-selected groups to form over time could lead to a free-riding effect where certain group members rely on others to complete the activities for them. A line of further inquiry is to investigate the outcomes of different group formation strategies. For instance, experimenting with randomly assigning groups formed over longer periods. This would be of interest to socio-constructivist learning design.

Second, the current version of Arleno only allows activities that structure Garrison et al.'s (1999) stages of practical inquiry. While supporting high levels of cognitive presence, the activities are time-consuming to complete. Each activity demands between 45-minutes and one hour of class time. Since the functionality to anchor annotations to text-based resources is developed, it would be straightforward for a programmer to expand the project with activities that allow quick engagements with text-based content. As such, it would be interesting to

develop and test activities that engage students in a more time-efficient way; for instance, quizzes and word clouds attached to the content could support quick, easy activities.

Third, it would be interesting to design a methodology exploring the entirety of the group-inquiry process. This study only measured, using Garrison et al.'s (1999) practical inquiry model, the outcomes of the group inquiry and not the process. A line of inquiry would be to develop a methodology objectively capturing the process leading to the inquiry outcomes. For instance, recording the breakout rooms and using learning analytics could establish granular levels of engagement. Overall, this would allow further barriers, and enablers to inquiry to be established.

Fourth, partial participation in the inquiry-based SA activities was a barrier at odds with productive inquiry across both interventions. I established that raising the levels of what Buder (2011) calls behavioural awareness within Arleno could address partial participation. Behavioural awareness is the level an online environment informs learners about the actions of their peers. As such, a future line of work could be to experiment with incorporating features such as a leaderboard ranking interactions with Arleno. Such features would ensure that it is clear the extent that learners are interacting with the SA environment.

Finally, in line with the tradition of DBR, I would like to see the "implementation and spread of the solution" (McKenney and Reeves, 2012, p. 80). The group inquiry-based SA activities supported by Arleno solved the problem of students taking a surface-level approach towards engaging in text-based resources (Marton and Säljö, 1976). However, the solution has only been tested in the narrow context of my practice setting. As such, I would like to support teachers and learning designers to test Arleno in wider practice settings.

Bibliography

Akyol, Z., Arbaugh, J. B., Cleveland-Innes, M., Garrison, D. R., Ice, P., Richardson, J. C. and Swan, K. (2009), 'A Response to the Review of the Community of Inquiry Framework', **23**(2), 123–136.

Akyol, Z. and Garrison, D. R. (2011), 'Understanding cognitive presence in an online and blended community of inquiry: Assessing outcomes and processes for deep approaches to learning', *British Journal of Educational Technology* **42**(2), 233–250.

Alzahrani, M. G. (2017), 'The effect of using online discussion forums on students' learning.'.

Anderson, T. and Shattuck, J. (2012), 'Design-based research: A decade of progress in education research', *Educational Researcher* **41**(1), 16–25.

Annand, D. (2011), 'Social presence within the community of inquiry framework', *International Review of Research in Open and Distance Learning* **12**(5), 38–54.

Azmuddin, R. A., Fariza, N., Nor, M. and Hamat, A. (2020), 'Facilitating Online Reading Comprehension in Enhanced Learning Environment Using Digital Annotation Tools', *IAFOR Journal of Education: Tehcnology in Education* **8**(2), 7–27.

Azmuddin, R. A., Nor Fariza, M. N. and Hamat, A. (2018), 'Using iREAD in understanding online reading strategies applied by science and technology students', *International Journal of Web-Based Learning and Teaching Technologies* **13**(3), 18–32.

Baier, K., Hendricks, C., Gorden, K. W., Hendricks, J. E. and Cochran, L. (2011),

'College students' textbook reading, or not!', *American Reading Forum Annual Yearbook* **31**(31), 385–402.

Bakker, A. and Eerde, D. v. (2015), An introduction to design-based research with an example from statistics education, *in* 'Approaches to qualitative research in mathematics education', Springer, pp. 429–466.

Benitez, C., Ana, Q., Gonzalez, P., Ochoa, C. and Vargas, A. (2020), 'The impact of online annotation tools on students academic performance in a distance university program', *Turkish Online Journal of Distance Education* **21**(2), 167 – 177.

Berry, T., Cook, L., Hill, N. and Stevens, K. (2010), 'An Exploratory Analysis of Textbook Usage and Study Habits: Misperceptions and Barriers to Success', *College Teaching* **59**(1), 31–39.

Biggs, J. (1999), 'What the student does: Teaching for enhanced learning', *International Journal of Phytoremediation* **21**(1), 57–75.

Biggs, J. and Tang, C. (2011), *Teaching for quality learning at university*, McGraw-hill education (UK).

Bodemer, D. and Dehler, J. (2011), 'Group awareness in CSCL environments', *Computers in Human Behavior* **27**(3), 1043–1045.

Bodner, G. M. (1986), 'Constructivism: A theory of knowledge', *Journal of chemical education* **63**(10), 873.

Bonner, A. (2015), 'Insider-outsider', *Nurse Researcher* **9**(4), 7–19.

Bråten, I. and Braasch, J. L. (2017), Key issues in research on students' critical reading and learning in the 21st century information society, *in* 'Improving reading and reading engagement in the 21st century', Springer, pp. 77–98.

Braun, V. and Clarke, V. (2006), 'Using thematic analysis in psychology', *Qualitative research in psychology* **3**(2), 77–101.

Braun, V. and Clarke, V. (2012), Thematic analysis., *in* 'APA handbook of research methods in psychology, Vol 2: Research designs: Quantitative,

qualitative, neuropsychological, and biological.', APA handbooks in psychology®., American Psychological Association, Washington, DC, US, pp. 57–71.

Brooks, C. F. and Young, S. L. (2016), 'Exploring communication and course format: Conversation frequency and duration, student motives, and perceived teacher approachability for out-of-class contact', *International Review of Research in Open and Distance Learning* **17**(5), 235–247.

Brown, A. L. (1992), 'Design experiments: Theoretical and methodological challenges in creating complex interventions in classroom settings', *The journal of the learning sciences* **2**(2), 141–178.

Brush, A. J., Bargeron, D., Gupta, A. and Cadiz, J. J. (2001), 'Robust annotation positioning in digital documents', *Conference on Human Factors in Computing Systems - Proceedings* pp. 285–292.

Buder, J. (2011), 'Group awareness tools for learning: Current and future directions', *Computers in Human Behavior* **27**(3), 1114–1117.

Butz, N. T. and Stupnisky, R. H. (2017), 'Improving student relatedness through an online discussion intervention: The application of self-determination theory in synchronous hybrid programs', *Computers and Education* **114**, 117–138.

Caskurlu, S., Richardson, J. C., Maeda, Y. and Kozan, K. (2021), 'The qualitative evidence behind the factors impacting online learning experiences as informed by the community of inquiry framework: A thematic synthesis', *Computers and Education* **165**(2021).

Cesareni, D., Cacciamani, S. and Fujita, N. (2015), 'Role taking and knowledge building in a blended university course', *International Journal of Computer-Supported Collaborative Learning* **11**(1), 9–39.

Chan, J. W. and Pow, J. W. (2020), 'The role of social annotation in facilitating collaborative inquiry-based learning', *Computers & Education* **147**, 103787.

Chen, C. H. and Su, C. Y. (2019), 'Using the BookRoll e-book system to promote self-regulated learning, self-efficacy and academic achievement for university students', *Educational Technology and Society* **22**(4), 33–46.

Chen, J. and Yen, J. C. (2013), 'Hypertext annotation: Effects of presentation formats and learner proficiency on reading comprehension and vocabulary learning in foreign languages', *Computers and Education* **63**, 416–423.

Clapp, J., DeCoursey, M., Lee, S. W. S. and Li, K. (2021), 'Something fruitful for all of us: Social annotation as a signature pedagogy for literature education', *Arts and Humanities in Higher Education* **20**(3), 295–319.

Cohen, L., Manion, L. and Morrison, K. (2011), *Research methods in education*, 7 edn, Routledge.

Cohn, M. (2004), *User stories applied: For agile software development*, Addison-Wesley Professional.

Collins, A. (1992), Toward a design science of education, *in* E. Scanlon and T. O'Shea, eds, 'New Directions in Educational Technology', Springer Berlin Heidelberg, Berlin, Heidelberg, pp. 15–22.

Commander, N., Zhao, Y., Gallagher, P. and You, Y. (2016), 'Cross-national online discussions: international learning experiences with American and Chinese students in higher education', *Innovations in Education and Teaching International* **53**(4), 365–374.

Creswell, J. W. (2014), *Research Design Qualitative, Quantitative and Mixed Methods Approaches*, 4 edn, SAGE Publications, London.

Creswell, J. W. and Clark, V. L. P. (2017), *Designing and conducting mixed methods research*, SAGE Publications, London.

Dahl, J. E. (2016), 'Students' framing of a reading annotation tool in the context of research-based teaching', *Turkish Online Journal of Educational Technology* **15**(1), 92–109.

Davies, W. M. (2009), 'Groupwork as a form of assessment: Common problems and recommended solutions', *Higher Education* **58**(4), 563–584.

Davis, M. R. (2010), 'Social networking goes to school', *The Education Digest* **76**(3), 14–19.

Design-Based Research Collective (2003), 'Design-based research: An emerging paradigm for educational inquiry', *Educational Researcher* **32**(1), 5–8.

Dewey, J. (1933), *How we think: A restatement of the relation of reflective thinking to the educative process*, DC Heath, Boston.

Dillenbourg, P. and Jermann, P. (2010), 'Technology for classroom orchestration', pp. 525–552.

Dugartsyrenova, V. A. and Sardegna, V. G. (2019), 'Raising intercultural awareness through voice-based telecollaboration: perceptions, uses, and recommendations', *Innovation in Language Learning and Teaching* **13**(3), 205–220.

Finlay, L. (1998), 'Reflexivity: An Essential Component for All Research?', *British Journal of Occupational Therapy* **61**(10), 453–456.

Fiock, H. (2020), 'Designing a Community of Inquiry in Online Courses', *The International Review of Research in Open and Distributed Learning* **21**(1), 134–152.

Förster, M., Weiser, C. and Maur, A. (2018), 'How feedback provided by voluntary electronic quizzes affects learning outcomes of university students in large classes', *Computers and Education* **121**(2018), 100–114.

Friess, E. and Lam, C. (2018), 'Cultivating a Sense of Belonging: Using Twitter to Establish a Community in an Introductory Technical Communication Classroom', *Technical Communication Quarterly* **27**(4), 343–361.

Garrison, D. R., Anderson, T. and Archer, W. (2001), 'Critical thinking, cognitive presence, and computer conferencing in distance education', *International Journal of Phytoremediation* **21**(1), 7–23.

Garrison, D. R. and Arbaugh, J. B. (2007), 'Researching the community of inquiry framework: Review, issues, and future directions', *Internet and Higher Education* **10**(3), 157–172.

Garrison, R. D., Anderson, T. and Archer, W. (1999), 'Critical inquiry in a text-based environment: Computer conferencing in higher education', *The internet and higher education* **2**(2-3), 87–105.

Garrison, R. D., Anderson, T. and Archer, W. (2000), 'Critical Inquiry in a Text-Based Environment', *The Internet and Higher Education* **2**(2), 87–105.

Garrison, R. D., Cleveland-Innes, Martha, Fung and Shing, T. (2010), 'Exploring causal relationships among teaching, cognitive and social presence: Student perceptions of the community of inquiry framework', *Internet and Higher Education* **13**(1-2), 31–36.

Gayoso-Cabada, J., Goicoechea-de Jorge, M., Gómez-Albarrán, M., Sanz-Cabrerizo, A., Sarasa-Cabezuelo, A. and Sierra, J. L. (2019), 'Ontology-enhanced educational annotation activities', *Sustainability (Switzerland)* **11**(16).

Gronseth, S. and Hebert, W. (2019), 'GroupMe: Investigating Use of Mobile Instant Messaging in Higher Education Courses', *TechTrends* **63**(1), 15–22.

Gunawardena, C. N., Lowe, C. A. and Anderson, T. (1997), 'Analysis of a global online debate and the development of an interaction analysis model for examining social construction of knowledge in computer conferencing', *Journal of educational computing research* **17**(4), 397–431.

Harmon, O. R. and Tomolonis, P. A. (2019), 'The effects of using facebook as a discussion forum in an online principles of economics course: Results of a randomized controlled trial', *International Review of Economics Education* **30**(2019), 100157.

Harris, U. S. (2017), 'Virtual Partnerships: Engaging Students in E-service Learning Using Computer-mediated Communication', *Asia Pacific Media Educator* **27**(1), 103–117.

Hassel, S. and Ridout, N. (2018), 'An investigation of first-year students' and lecturers' expectations of university education', *Frontiers in Psychology* **8**(JAN).

Herrington, J., McKenney, S., Reeves, T. and Oliver, R. (2007), Design-based research and doctoral students: Guidelines for preparing a dissertation proposal, *in* 'EdMedia+ Innovate Learning', Association for the Advancement of Computing in Education (AACE), pp. 4089–4097.

Hoeft, M. E. (2012), 'Why University Students Don't Read: What Professors Can Do To Increase Compliance', *International Journal for the Scholarship of Teaching and Learning* **6**(2).

Inel Ekici, D. (2018), 'Development of pre-service teachers' teaching self-efficacy beliefs through an online community of practice', *Asia Pacific Education Review* **19**(1), 27–40.

Jan, S. K. and Vlachopoulos, P. (2018), 'Influence of learning design of the formation of online communities of learning', *International Review of Research in Open and Distance Learning* **19**(4), 1–16.

Kahu, E. R. (2013), 'Framing student engagement in higher education', *Studies in higher education* **38**(5), 758–773.

Kalir, J. H., Morales, E., Fleerackers, A. and Alperin, J. P. (2020), '"When I saw my peers annotating": Student perceptions of social annotation for learning in multiple courses', *Information and Learning Science* **121**(3-4), 207–230.

Kerr, M. M. and Frese, K. M. (2017), 'Reading to learn or learning to read? Engaging college students in course readings', *College Teaching* **65**(1), 28–31.

Kersh, S. E. and Skalak, C. (2018), 'From distracted to recursive reading: Facilitating knowledge transfer through annotation software', *Digital Humanities Quarterly* **12**(2).

Khalid, F. (2019), 'Students' identities and its relationships with their engagement in an online learning community', *International Journal of Emerging Technologies in Learning* **14**(5), 4–19.

Kirschner, P., Strijbos, J.-W., Kreijns, K. and Beers, P. J. (2004), 'Designing Electronic Collaborative Learning Environments', *ETR&D* **52**(3), 47–66.

Kornelakis, A. and Petrakaki, D. (2020), 'Embedding employability skills in UK higher education: Between digitalization and marketization', *Industry and Higher Education* **34**(5), 290–297.

Kramer, A. D., Guillory, J. E. and Hancock, J. T. (2014), 'Experimental evidence of massive-scale emotional contagion through social networks', *Proceedings of the National Academy of Sciences* **111**(24), 8788–8790.

Kreijns, K. (2004), Sociable CSCL environments (Doctoral Disseration, PhD thesis, Datawyse/Universitaire Pers Maastricht.

Kreijns, K., Kirschner, P. A. and Jochems, W. (2003), 'Identifying the pitfalls for social interaction in computer-supported collaborative learning environments: a review of the research', *Computers in Human Behavior* **19**(3), 335–353.

Lacković, N. (2020), 'Thinking with digital images in the post-truth era: A method in critical media literacy', *Postdigital Science and Education* **2**(2), 442–462.

Laurillard, D. (2013), *Teaching as a design science: Building pedagogical patterns for learning and technology*, Routledge, New York.

Law, K. M., Geng, S. and Li, T. (2019), 'Student enrollment, motivation and learning performance in a blended learning environment: The mediating effects of social, teaching, and cognitive presence', **136**(March), 1–12.

Lee, C. and Teh, L. (2016), 'Educational use of facebook by undergraduate students in malaysia higher education: A case study of a private university', *Social Media and Technology* **1**(1), 1–8.

Lee, S.-M. (2014), 'The relationships between higher order thinking skills, cognitive density, and social presence in online learning', *The internet and higher education* **21**(2014), 41–52.

Li, S. C., Pow, J. W. and Cheung, W. C. (2015), 'A delineation of the cognitive processes manifested in a social annotation environment', **31**(1), 1–13.

Liu, Z., Pinkwart, N., Liu, H., Liu, S. and Zhang, G. (2018), 'Exploring students' engagement patterns in SPOC forums and their association with course performance', *Eurasia Journal of Mathematics, Science and Technology Education* **14**(7), 3143–3158.

Lowden, K., Hall, S., Elliot, D. and Lewin, J. (2011), 'Employers' perceptions of the employability skills of new graduates', *London: Edge Foundation* .

Mantle, R. (2020), Higher education student statistics: UK, 2018/19 - subjects studied, Technical report, HESA.

Marton, F. (1988), Describing and improving learning, *in* 'Learning strategies and learning styles', Springer, pp. 53–82.

Marton, F. and Säljö, R. (1976), 'on Qualitative Differences in Learning: I-Outcome and Process*'.

McKenney, S., Nieveen, N. and van den Akker, J. (2006), Design research from a curriculum perspective, *in* 'Educational design research', Routledge, pp. 79–102.

McKenney, S. and Reeves, C, T. (2012), *Conducting Educational Design Research*, Routledge, London, England.

Meyer, J. H. and Land, R. (2005), 'Threshold concepts and troublesome knowledge (2): Epistemological considerations and a conceptual framework for teaching and learning', *Higher education* **49**(3), 373–388.

Miller, K., Lukoff, B., King, G. and Mazur, E. (2018), 'Use of a social annotation platform for pre-class reading assignments in a flipped introductory physics class', *Frontiers in Education* **3**, 8.

Miller, K., Zyto, S., Karger, D., Yoo, J. and Mazur, E. (2016), 'Analysis of student engagement in an online annotation system in the context of a flipped introductory physics class', *Physical Review Physics Education Research* **12**(2), 1 – 10.

Molinillo, S., Aguilar-Illescas, R., Anaya-Sánchez, R. and Vallespín-Arán, M. (2018), 'Exploring the impacts of interactions, social presence and emotional

engagement on active collaborative learning in a social web-based environment', *Computers & Education* **123**, 41–52.

Morgan, D. L. (2014), 'Pragmatism as a Paradigm for Social Research', *Qualitative Inquiry* **20**(8), 1045–1053.

Morse, J. M. and Niehaus, L. (2016), *Mixed Method Design: Principles and Procedures*, Routledge, Taylor & Francis Group, New York.

O'Dell, K. (2020), 'Modern Marginalia: Using Digital Annotation in the Composition Classroom', *Computers and Composition* **56**(2020), 102570.

Olson, E. D. and Brown, E. (2018), 'Perceptions of Students in an Event Management Program of Annotation Systems and Their Influence on Student Learning', *Journal of Hospitality and Tourism Education* **30**(2), 118–126.

Oriogun, P. K. (2009), 'Detecting aspects of critical thinking by cleaning online message transcript through code-recode', *American Journal of Distance Education* **23**(1), 34–50.

Pantic, I. (2014), 'Online social networking and mental health', *Cyberpsychology, Behavior, and Social Networking* **17**(10), 652–657.

Pennycook, G. and Rand, D. G. (2021), 'The psychology of fake news', *Trends in cognitive sciences* **25**(5), 388–402.

Pereira, J. C. and Russo, R. d. F. (2018), 'Design thinking integrated in agile software development: A systematic literature review', *Procedia Computer Science* **138**, 775–782.

Pintrich, P. R., Marx, R. W. and Boyle, R. A. (1993), 'Beyond cold conceptual change: The role of motivational beliefs and classroom contextual factors in the process of conceptual change', *Review of Educational research* **63**(2), 167–199.

Pool, J. and Laubscher, D. (2016), 'Design-based research: is this a suitable methodology for short-term projects?', *Educational Media International* **53**(1), 42–52.

Posey, L., Davis, S., Briggs, L. and Sheingold, B. (2014), 'Communities of Inquiry in Online Nurse Practitioner Education', *Journal for Nurse Practitioners* **10**(10), e77–e86.

Potts, L. and Harrison, A. (2013), Interfaces as rhetorical constructions: reddit and 4chan during the boston marathon bombings, *in* 'Proceedings of the 31st ACM international conference on Design of communication', pp. 143–150.

QAA (2018), 'UK quality code for higher education: Advice and guidance–work-based learning'.

Ragusa, A. T. (2017), 'Technologically-mediated communication: student expectations and experiences in a FOMO society', *International Journal of Educational Technology in Higher Education* **14**(1), 1–20.

Reeves, T. (2006), Design research from a technology perspective, *in* 'Educational Design Research', Routledge, pp. 64–78.

Richardson, J. C. and Ice, P. (2010), 'Investigating students' level of critical thinking across instructional strategies in online discussions', *Internet and Higher Education* **13**(1-2), 52–59.

Rourke, L. and Kanuka, H. (2009), 'Learning in Communities of Inquiry: A Review of the Literature', *International Journal of E-Learning and Distance Education* **23**(1), 19–48.

Sadaf, A. and Olesova, L. (2017), 'Enhancing Cognitive Presence in Online Case Discussions With Questions Based on the Practical Inquiry Model', *American Journal of Distance Education* **31**(1), 56–69.

Sadaf, A., Wu, T. and Martin, F. (2021), 'Cognitive Presence in Online Learning: A Systematic Review of Empirical Research from 2000 to 2019', *Computers and Education Open* **2**, 100050.

Sheard, J., Carbone, A. and Hurst, A. J. (2010), 'Student engagement in first year of an ICT degree: Staff and student perceptions', *Computer Science Education* **20**(1), 1–16.

Shin, Y., Kim, D., Jung, J., Journal, S., April, N., Shin, Y., Kim, D. and Jung, J. (2018), 'The Effects of Representation Tool (Visible-Annotation) Types to Support Knowledge Building in Computer-Supported Collaborative Learning', *International Forum of Educational Technology and Society* **21**(2), 98–110.

St Clair-Thompson, H., Graham, A. and Marsham, S. (2018), 'Exploring the Reading Practices of Undergraduate Students', *Education Inquiry* **9**(3), 284–298.

Starcher, K. and Proffitt, D. (2011), 'Encouraging Students to Read: What Professors Are (and Aren't) Doing About It', *International Journal of Teaching and Learning in Higher Education* **23**(3), 396–407.

Stenbom, S. (2018), 'A systematic review of the Community of Inquiry survey', *Internet and Higher Education* **39**(2018), 22–32.

Stephens, R., Spierer, D. K. and Katehis, E. (2018), 'Effect of swearing on strength and power performance', *Psychology of Sport and Exercise* **35**, 111–117.

Stolaki, A. and Economides, A. A. (2018), 'The creativity challenge game: An educational intervention for creativity enhancement with the integration of information and communication technologies (icts)', *Computers & Education* **123**, 195–211.

Strong, J. T. and Anderson, R. E. (1990), 'Free-riding in group projects: Control mechanisms and preliminary data', *Journal of marketing education* **12**(2), 61–67.

Sun, Y. and Gao, F. (2016), 'Comparing the use of a social annotation tool and a threaded discussion forum to support online discussions', *Internet and Higher Education* **32**, 72–79.

Swan, K., Day, S. L., Bogle, L. R. and Matthews, D. B. (2014), 'A collaborative, design-based approach to improving an online program', *Internet and Higher Education* **21**, 74–81.

Taylor, J. and House, B. (2010), 'An exploration of identity, motivations and concerns of non-traditional students at different stages of higher education.', *Psychology teaching review* **16**(1), 46–57.

Trowler, V. (2015), 'Negotiating contestations and 'chaotic conceptions': Engaging 'non-traditional'students in higher education', *Higher Education Quarterly* **69**(3), 295–310.

Tuhkala, A. and Kärkkäinen, T. (2018), 'Using Slack for computer-mediated communication to support higher education students' peer interactions during Master's thesis seminar', *Education and Information Technologies* **23**(6), 2379–2397.

Unluer, S. (2012), 'Being an insider researcher while conducting case study research', *Qualitative Report* **17**(29), 1–14.

Van den Akker, J. (1999), Principles and methods of development research, *in* 'Design approaches and tools in education and training', Springer, pp. 1–14.

Vaughan, N. D., Cleveland-innes, M. and Garrison, D. R. (2013), *Teaching in Blended Learning Environments: Creating and Sustaining Communities of Inquiry*, Athabasca University Press.

Vinagre, M. and Corral Esteban, A. (2018), 'Evaluative language for rapport building in virtual collaboration: an analysis of appraisal in computer-mediated interaction', *Language and Intercultural Communication* **18**(3), 335–350.

Vorobel, O., Voorhees, T. and Gokcora, D. (2018), 'ESL students' perceptions of using a social bookmarking tool for the development of reading in a second language', *jaltcalljournal* **14**(3), 191–210.

Vygotsky, L. S. (1980), *Mind in society: The development of higher psychological processes*, Harvard university press.

Wakefield, J., Frawley, J. K., Tyler, J. and Dyson, L. E. (2018), 'The impact of an iPad-supported annotation and sharing technology on university students' learning', *Computers and Education* **122**, 243–259.

Walker, D. (2006), Toward productive design studies, *in* 'Educational design research', Routledge, pp. 20–26.

Wei, H.-C., Peng, H. and Chou, C. (2015), 'Can more interactivity improve learning achievement in an online course? effects of college students' perception and actual use of a course-management system on their learning achievement', *Computers & Education* **83**, 10–21.

Wijenayake, S., van Berkel, N., Kostakos, V. and Goncalves, J. (2021), 'Quantifying Determinants of Social Conformity in an Online Debating Website', *International Journal of Human-Computer Studies* **158**(2022), 102743.

Yeh, H. C., Hung, H. T. and Chiang, Y. H. (2017), 'The use of online annotations in reading instruction and its impact on students' reading progress and processes', *ReCALL* **29**(1), 22–38.

Yilmaz, F. G. K. and Keser, H. (2016), 'The impact of reflective thinking activities in e-learning: A critical review of the empirical research', *Computers and Education* **95**, 163–173.

Zarzour, H. and Sellami, M. (2017), 'A linked data-based collaborative annotation system for increasing learning achievements', *Educational Technology Research and Development* **65**(2), 381–397.

Zyto, S., Karger, D., Ackerman, M. and Mahajan, S. (2012), Successful classroom deployment of a social document annotation system, *in* 'Proceedings of the sigchi conference on human factors in computing systems', pp. 1883–1892.

Chapter A: Emails

A.1 Outreach

Invite for a quick informal chat

Hey [[participant name]],

I hope you are well, and are looking forward to the summer.

As an active member of research methods, I would very much like to have a quick (40 minute) informal teams chat with you.

The discussion is surrounding my research, and I would love to get your input. You'd be helping me and future students.

Are you free today or later this week?

Hope to hear from you; either way, have a great summer.

Joe

A.2 Invite

Hello [[participant name]],

I very much appreciate you volunteering to help with my research.

The interview should take no more than 40 minutes and is nothing more than an informal chat.

Before we meet, you may want to click this link to read the participant information - it contains a little more detail on what will be involved. Should you have any questions or concerns, I will go over this document with you at the start of our interview. Further to this, I will also send you an email asking you to formally consent to this research.

Other than reading the participant information, there is no preparation required.

Thanks for participating,

Joe

Chapter B: Interview Participants

Participant pseudonym	Age	Gender	Course
DBRC1 Interview Sample			
P1	23	F	BSc (Hons) Digital and Technology Solutions
P2	21	M	BSc (Hons) Digital and Technology Solutions
P3	24	M	BSc (Hons) Digital and Technology Solutions
P4	21	M	BSc (Hons) Digital and Technology Solutions
P5	33	M	BSc (Hons) Digital and Technology Solutions
P6	22	M	BSc (Hons) Digital and Technology Solutions
P7	21	F	BSc (Hons) Computing
P8	23	M	BSc (Hons) Computing
P9	23	M	BSc (Hons) Cyber Security
P10	26	M	BSc (Hons) Software Engineering
P11	22	M	BSc (Hons) Computing
DBRC2 Interview Sample			
P12	21	F	BSc (Hons) Software Engineering
P13	21	M	BSc (Hons) Software Engineering
P14	21	M	BSc (Hons) Software Engineering
P15	22	M	BSc (Hons) Computer Systems and Network Engineering
P16	20	F	BSc (Hons) Cyber Security
P17	28	F	BSc (Hons) Digital Design and Web Development
P18	20	M	BSc (Hons) Software Engineering
P19	21	F	BSc (Hons) Cyber Security
P20	28	M	BSc (Hons) Cyber Security Management
P21	22	M	BSc (Hons) Software Engineering
P22	21	M	BSc (Hons) Software Engineering

Table B.1: Interview Participants. P1-P12 were interviewed after the first intervention, P11-P22 after the second.

Chapter C: Ethical Documents

Department of Educational Research
County South, Lancaster University, LA1 4YD, UK
Tel: +44 (0) 1524 5926893

Participant information sheet

I am a, part-time, PhD student at Lancaster University, and I would like to invite you to take part in a research study about your experiences of the online conversation tool, developed by myself, that you have been using throughout this current unit. Please take time to read the following information carefully before you decide whether you wish to take part.

What is the study about?
This study aims to develop, understand (from the students' perspective) and introduce an innovative new discussion environment into the learning setting.

Why have I been invited?
I have approached you because you are participating in a unit where I will be evaluating the new discussion environment mentioned above. As such, your future experiences and interactions will provide a valuable insight into the characteristics of this new tool.

What will I be asked to do if I take part?
If you decide to take part, your interactions in the online discussion platform will be subject to analysis. Further to this, you will be invited to complete an anonymous survey. Your interactions with these data collection methods will remain anonymous.

You may also be invited to participate, in either or both, a 45-minute-long focus group and a one-to-one interview. These sessions will take place, remotely, over Microsoft Teams. Audio, video and screen sharing activity will be recorded and securely saved to Microsoft Stream.

The focus group will have open, honest and respectful opinion exchange, and any information disclosed within the focus group remains confidential to the group, and you will not reveal the names of participants outside the focus group.

Participation in the surveys, focus groups and interviews is optional.

What are the possible benefits from taking part?
Your participation feeds into the understanding and development of an online discussion environment that is intended to support the wider university learning experience. You will be indirectly helping students who may benefit from the use of this tool in the future.

Do I have to take part?
No. It's completely up to you to decide whether or not you take part.

What if I change my mind?
If you change your mind, you are free to withdraw, all or part of the data used in the study**, within two weeks** of an interview or focus group taking place. If you no longer want your interactions in the online discussion environment used in the study, you should do this within **4 weeks of volunteering to take part in this study.** You should note, survey specific data cannot be removed - this is due to the survey data being anonymous. Withdrawal requests should be sent to joe.appleton@solent.ac.uk . On receiving the request, relevant data will be removed from the study. If you withdraw from the focus group, the I'll do my best to disregard your views when analysing the focus group data, but this will not always be possible

What are the possible disadvantages and risks of taking part?

There are no clearly identified risks associated with taking part in this study. If you are required to be interviewed or take part in a focus group, then there is a time commitment of no more than 60 minutes per session.

Will my data be identifiable?
After the interview, focus group and online interaction analysis, only myself and Natasa Lackovic (my PhD supervisor) will have access to your data. I will keep all personal information about you (e.g. your name and other information about you that can identify you) confidential, that is I will not share it with others. I will remove any personal information from the written record of your contribution. All reasonable steps will be taken to protect the anonymity of the participants involved in this project. Participants in the focus group will be asked not to disclose information outside of the focus group and with anyone not involved in the focus group without the relevant person's permission.

How will the data be recorded and stored?
Focus groups and interviews will take place, remotely, over Microsoft Teams. Audio, video and screen sharing activity will be recorded and securely saved to Microsoft Stream. Copies will also be transferred to One Drive shared information space and/or encrypted files on my computer. With regards to the surveys, the data will anonymous and stored in university be database. All the data will be kept for a minimum of 10 years and subsequently destroyed.

How will we use the information you have shared with us and what will happen to the results of the research study?
I will use it for research purposes only and will aim to anonymise and disseminate the results.
As such, the processed results could appear in journal articles, my PhD thesis, conference papers and presentations.

When writing up the findings, I would like to reproduce some of the views and ideas you shared with me. However, although I will use your exact words, **all steps will be taken to protect your anonymity in** my publications.

What if I have a question or concern?
If you have any queries or if you are unhappy with anything that happens concerning your participation in the study, please contact myself: Joe Appleton, Tel: 07986836915, Email: joe.appleton@solent.ac.uk

If you have any concerns or complaints that you wish to discuss with a person who is not directly involved in the research, you can also contact: Prof. Paul Ashwin, Head of Department, Email: paul.ashwin@lancaster.ac.uk Department of Educational Research, County South, Lancaster University, Lancaster, LA1 4YL, United Kingdom. Tel : +44 (0) 1524 594443

Sources of support
In some projects, sensitive and potentially distressing topics may be discussed as part of the research. In such cases, it is good practice to add sources of support participants can turn to.

This study has been reviewed and approved by the Faculty of Arts and Social Sciences and Lancaster Management School's Research Ethics Committee.

For further information about how Lancaster University processes personal data for research purposes and your data rights please visit our webpage: www.lancaster.ac.uk/research/data-protection

Thank you for considering your participation in this project.

CONSENT FORM

Project Title: A design based research exploration into constructing a learning environment that can support meaningful online discussion

Name of Researcher: Joe Appleton
Email: joe.appleton@solent.ac.uk

Please tick each box

1. I confirm that I have read and understand the information sheet for the above study. I have had the opportunity to consider the information, ask questions and have had these answered.	
2. I understand that my participation is voluntary and that I am free to withdraw, without giving any reason. at any time during my participation in this study and within 2 weeks after taking part in the focus group or interview. With regards to your interactions being used in the study, you can withdraw up to 4 weeks after the study commencing. 3. I understand the conditions and procedure of participation in focus group and interviews. 4. I understand that as part the focus group I will take part in, my data is part of the ongoing conversation and cannot be destroyed. I understand that the researcher will try to disregard my views when analysing the focus group data, but I am aware that this will not always be possible.	
5. If I am participating in the focus group I understand that any information disclosed within the focus group remains confidential to the group, and I will not refer to participants with or in front of anyone who was not involved unless I have the relevant person's express permission	
6. I understand that any information given by me may be used in future reports, academic articles, publications or presentations by the researcher/s, but my personal information will not be included and all reasonable steps will be taken to protect the anonymity of the participants involved in this project. Anonymised data will be offered to a data repository and will be made available to genuine research for re-use.	
7. I understand that my name will not appear in any reports, articles or presentation without my consent.	
8. I understand that any interviews or focus groups will be audio-recorded and transcribed and that data will be protected on encrypted devices and kept secure.	
9. I understand that data will be kept according to University guidelines for a minimum of 10 years after the end of the study.	
10. I agree to take part in the above study.	

_____ _____ _____

Name of Participant Date Signature

I confirm that the participant was given an opportunity to ask questions about the study, and all the questions asked by the participant have been answered correctly and to the best of my ability. I confirm that the individual has not been coerced into giving consent, and the consent has been given freely and voluntarily.

Signature of Researcher _____ _____ **Date** ___15/12/2020_____

One copy of this form will be given to the participant and the original kept in the files of the researcher at Lancaster University