Good Issues and bad tidying: what GitHub can tell us about agency in project-based group modelling work for higher education.

A thesis submitted to fulfil requirements for the degree of Doctor of Philosophy

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Statement of originality

This is to certify that:

I. This thesis comprises only my original work towards the PhD Degree,

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III. The thesis does not exceed the word length for this degree,

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I certify that the intellectual content of this thesis is the product of my own work and that all the assistance received in preparing this thesis proposal and sources have been acknowledged.

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Abstract

Collaborative project work in technology-enabled environments at university is essential for learners to become ready for an increasingly global, complex, and virtualised workplace. Research on effective pedagogical and technical design for computer supported collaborative learning in higher education (CSCL) has often taken place in synchronous contexts, using specialised technology platforms. However, large-scale changes to work and education resulting from the COVID-19 pandemic necessitate the development of pedagogical and research approaches that support students working asynchronously, in distributed teams, using collaboration platforms that extend beyond institutional infrastructure.

Within the field of CSCL, knowledge building research has shown collaboration to be a complex systems phenomenon, involving the intersection of individual and collective efforts to actively advance the group's shared knowledge, but studies analysing interaction data have been resource-intensive to conduct. Contemporary workplace platforms such as professional knowledge environments have multiple design affordances consistent with knowledge building principles, as well as the capacity to generate rich data about user activity. However, we have little understanding to date as to how these environments can support knowledge building pedagogies and facilitate associated research.

This study uses a case study approach and thematic analysis to investigate the activity of three university groups engaged in a collaborative modelling task over time. It investigates how agency emerges during project work in professional knowledge environments, and how the system interaction data can extend our understanding of effective collaboration processes. The results show that the GitHub platform can support knowledge building pedagogical designs in facilitating individual and collective agency in higher education group work, and provide insights into epistemic, regulative and relational aspects of learner behaviour at individual and group levels.

These findings extend our understanding of effective learning design to novel environments of a type likely to be used by our students in the workplace, and make design and methodological contributions to research on computer-supported collaborative learning.

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1. Introduction

1.1. Background

Working with others is a necessary part of being human and sharing our world. But it isn't always easy. As we are forced to recognise that the problems we face extend beyond traditional geopolitical boundaries, we are realising the solutions also involve global, networked, collaboration. Complex universal challenges such as harnessing space resources and responding to extreme weather events demand the coordination of multiple perspectives, skillsets, and communities. This work requires eliciting our own and each other's ideas, instincts, and understandings, and materialising them in a way that is shareable, then making sense of them from diverse perspectives through co-constructing iterative representations, until, together, we have generated new knowledge and productive and sustained activity at scale and beyond traditional boundaries. That isn't easy either.

In this increasingly globalised world, the nature and structure of both work and education are evolving to address these increasingly complex problems and diverse stakeholders (Yoon, 2018). Organisations now engage with distributed and often virtual teams (Cochrane et al., 2008; Nedic et al., 2011) extending across cultures and disciplines, with divergent experiences, mental models, and ways of knowing and doing (Ananth et al., 2011), manipulating symbols rather than materials and creating conceptual rather than material objects (Sawyer, 2008). This dynamic environment needs new kinds of knowledge workers to emerge from higher education, with broad practical skills in creating new ways of working together and an understanding of how to weave together diverse forms of knowledge and ways of knowing (Markauskaite & Goodyear, 2016). When employing new graduates, employers highlight teamwork (Hager, 2006; Lawrie et al., 2010; Pearce et al., 2007) critical thinking (Organisation for Economic Cooperation and Development (OECD), 2013), and the capacity to operate across cultural boundaries (Richards & Bilgin, 2012) as important professional skills, as well as expected educational outcomes (Luca & Tarricone, 2001; Oliver & Jorre De St Jorre, 2018; Organisation for Economic Cooperation and Development (OECD), 2013; Smith & MacGregor, 1992). These qualities are foundational to global citizenship (Oliver & Jorre De St Jorre, 2018), itself a key component of the graduate skillset (Barrie et al., 2009; Oliver & Jorre De St Jorre, 2018), and to the key competencies identified by the

Organisation for Economic Cooperation and Development (OECD) (Rychen, 2009) for meeting the challenges of a “globalized, rapidly changing and increasingly complex world” (p 2572). The modern “knowledge society” (Bereiter, 2002b; Scardamalia, 2002; Scardamalia et al., 2012; Tan et al., 2021) requires workers to produce new knowledge (Bereiter, 2002a; Paavola et al., 2012; Paavola & Hakkarainen, 2005; Scardamalia et al., 2012), by working on projects in groups (Barron, 2000; Bereiter, 2002b) in order for our networked society (Paavola & Hakkarainen, 2005) to frame and investigate increasingly wicked global problems (Ludvigsen & Steier, 2019) in an era characterised by uncertainty and change (Tan et al., 2021). With this shift in traditional modes of working, educational design and research needs to respond with a focus on preparing our learners to participate in project-focused, inter-disciplinary, cross-cultural teams which are often distributed across time zones and are frequently self-organised. For our graduates to be equipped for life after university, our learning environments must be designed for students to share and build on their own and their peers’ knowledge in the context of virtualised project-based teamwork with others.

1.2. Statement of the problem

Group work in higher education has been the subject of substantial research for decades, but from my own experience, and anecdotal evidence, it continues to be challenging for learners, instructors and researchers. In my own student experience, I tried a number of strategies to get around the inevitable issues: buddying up early on, choosing a topic early, doing the whole thing myself straight away then making exactly the changes the other person wanted even when I thought them inaccurate or inappropriate; and none of them were effective in improving the knowledge product. Working on assessment tasks with others (or ‘collaboration’) is considered important in Australian higher education degree courses at all levels, because employers want graduates to be able to succeed in a team without the need for workplace training on how to go about it. But if you think about it, people from those group projects that go bad at university are going into the workplace, meaning the same problems arise there, with slightly more complicated power dynamics, until we find ways to help people work together to create new knowledge. We need continued research on designing for collaboration to inform new pedagogical strategies that enable learners to participate in self-organised teams, and represent and share their individual knowledge in a way that benefits the collective.

Some university courses explicitly instruct students on the process of teamwork using one or other specific approach, for example, assigning individual roles (Johnson & Johnson, 1999; Smith & MacGregor, 1992) or actively managing team interactions (Zhang et al., 2009), others simply ask them to get together in a group and start work. Students are not keen on it either way, especially in the absence of a teacher keeping watch on how things are going. But with resources for universities tight, and teachers short of time, there is an economic as well as pedagogical need for groups to be self-sustaining, and potentially flexible when it comes to going outside traditional university collaboration settings. But to date, little research on group work has been conducted in the kind of professional knowledge environment settings students will encounter after graduation, with most research conducted on synchronous interactions within traditional university classrooms, learning management systems or customised collaboration environments. Exploring how established methods of designing for and investigating teamwork might operate in professional knowledge environments can extend our understanding of how new knowledge creation can be supported in these settings.

In any setting, the purpose of collaboration is not just about teamwork and problem solving. This thesis uses as its theoretical foundation the sociocultural view of learning (Leont'ev, 1978; Luria, 1971; Vygotsky, 1978), which proposes that participating in social and cultural processes with others is the fundamental way in which we change our consciousness. We use tools like language to engage our higher-order psychological processes with the world in which we live, and we and the world modify each other in turn (Vygotsky, 1978). These tools mediate our relations with each other (Vygotsky, 1997), and are also fundamental to the concept that knowledge can exist outside the individual; that an 'object' like a theorem which can be described by notation and written in a notebook then has a life of its own (Clark & Chalmers, 1998). As collaboration occurs and we collect distributed individual knowledge and consolidate it into a single source like that notebook, or a networked database, we construct a knowledge object that exceeds by far the knowledge of each individual mind (Hutchins, 2001). These objects operate across the boundary between people and ideas, and when enabled by technology can incorporate multiple layers of complex and situated meaning. Understanding how representations of complex ideas and systems can be materialised, shared and built on can engage learners in authentic knowledge creation practices as well as facilitate improved student outcomes.

When previously unarticulated knowledge – including a guess, an instinct or an feeling – has been materialised into a concrete representation that can be shared and added to, elaborated and refined, it has more power to be made into new knowledge (Paavola & Hakkarainen, 2005, 2014). When that process respects multiple voices and perspectives, better quality solutions to problems are developed (Paavola & Hakkarainen, 2005) and people are more committed to those solutions (Kaner, 2007). When the process is a systematic and purposeful development of that knowledge object, a balance is leveraged between the individual and group social processes to do with the development and the individual and group cognitive processes to do with the knowledge and object (Paavola & Hakkarainen, 2009). Within the Learning Sciences, setting a purposeful and authentic task allowing groups to develop their own processes and an environment with rich tools for both processes and knowledge object development over time is an evidence-based pedagogical design with a solid foundation (Scardamalia, 2002; Scardamalia et al., 2012; Tan et al., 2021) and the basis for 'trialogical learning', which centres shared artefact advancement using mediating technology in educational collaboration (Hakkarainen et al., 2006; Paavola & Hakkarainen, 2014; Paavola et al., 2011). These studies have demonstrated that it is critical that the mediating technology supports both the collaborative processes and iterative knowledge object co-construction, driving a need for evidence around the effectiveness of different environments for technology-mediated knowledge creation.

Even within this established pedagogical framework of supports and affordances, in a series of studies of groups engaged in collaboration tasks with similarly reputable designs, despite the groups in each study having the same task and similar university collaboration environments, they achieved quite different results because they behaved in different ways (Damşa, 2014; Damşa & Andriessen, 2012; Damşa et al., 2010). While we don't know the reasons for those behaviours, we know the observable difference between the groups that is associated with better outcomes. The concept of *agency* describes deliberate actions, involving planning and thinking as well as productional activity, at either individual or collective levels. *Epistemic agency* specifically relates to actions that advance knowledge. S*hared epistemic agency* is a phenomenon that arises when multiple group members actively participate in purposeful sequences of collaborative actions that move the knowledge object from one state to another. These *productive interactions* are self-organised processes and productive actions associated with improved outcomes from group project work. The development of epistemic agency is a focus for learning design in knowledge building pedagogies.

While the concept of agency has traditionally been located in individual actors as they engage in intentional responses to their circumstances (Emirbayer & Mische, 1998), the construct of shared epistemic agency in an educational context is a complex combination of joint knowledge- and process-related activity by groups as they manifest both their choices about action and their incremental knowledge through productive epistemic collaboration on tangible knowledge objects (Damşa et al., 2010). Knowledge objects themselves contain complexity: manifestations of content from instruction, logical structuring of context, personal re-structuring of relationships, and refinements of understanding that have emerged from the learning process (Entwistle, 2011). This materialisation of ideas is essential because the production process requires intentional action, that is, agency, and groups who engage in this together potentially engage in more knowledge creation (Damşa et al., 2010). Shared epistemic agency is a significant area of research because it contributes to cognitive and metacognitive activity, to self-management of productive engagement, and produces better learning outcomes (Damşa, 2014; Damşa & Andriessen, 2012; Damşa et al., 2010). However, understanding this phenomenon involves in-depth investigation of the trajectory of both individual and group interactions and activity in relation to the object of their collaboration because it is emergent, dynamic and might manifest in one way in one group and a different way in another (Damşa, 2014; Damşa, 2014; Damşa & Andriessen, 2012; Damşa et al., 2010). This requires a research approach that can accommodate multiple levels of analysis across multiple types, and substantial amounts, of data.

1.3. Purpose of the research

Researching collaboration has specific challenges because the data it generates is both rich and thick, across social, spatial and temporal configurations (Reimann, 2021), comprising situational and contextual factors (Cress, Oshima, et al., 2021). Data collection and analysis can be labour-intensive (Cress, Rosé, et al., 2021), and results might not be available in time to make a difference to the student participants themselves. Current studies are exploring group activity awareness tools (Crook, 2022; Reimann, 2018), interaction scripting (Fischer et al., 2013; Vogel et al., 2021; Wise & Schwarz, 2017), and the use of orchestrated teaching patterns in the classroom (Matuk et al., 2019), sometimes combined together (Crook, 2022 Matuk, 2019 #424) or with analytical tools such as Epistemic Network Analysis (Shaffer, 2017; Shaffer et al., 2009; Shaffer & Ruis, 2017) or Social Network Analysis (Oshima et al., 2015; Oshima et al., 2012; Palonen & Hakkarainen, 2000). There is increasing interest in 'dashboards' (Han et al., 2021; Ludvigsen & Steier, 2019) which often draw data from university Learning Management Systems about student access and interactions (Amarasinghe et al., 2021; Arriaran Olalde & Ipiña Larrañaga, 2019; Bennett & Folley, 2019). What these approaches do not always address is the kind of interactions that knowledge building and trialogical learning are interested in, which are iterative changes by multiple people to a knowledge object over time. Data about group activity might be in a proprietary format or limited by licence restrictions and requires a great deal of aggregation to see how particular interactions are related, and to what. Because institutional systems usually provide an upload function rather than an idea materialisation function we see a series of 'final' versions of – often – a single knowledge object with little idea as to the processes by which those technology-enabled iterations eventuated or the contributions of respective team members. Superficial aesthetic differences between some types of knowledge objects can also distract from the trajectory of shared knowledge advancement. As well as making it difficult to investigate how shared epistemic agency emerges, these constraints also present concerns in relation to designing learning environments that facilitate equitable assessment for group work.

To date, research has generally focused on synchronous student interactions, often of students who are co-located in the same physical space and time zone. However, with the shift to online instruction resulting from the COVID-19 pandemic and other disruptions to traditional modes of education, learners now frequently interact with peers and instructors asynchronously, from diverse locations, using various personal devices. This has implications for both research and instruction because while many key researchers have designed and implemented their own collaboration platforms with specific tools for working together, in higher education systems that are experiencing financial constraints, access to customised infrastructure accessible off-campus, by large classes, any time, and on any device may be limited. In our continued investigation of shared epistemic agency in collaborative learning, it is now necessary to go beyond institutional systems to those which are freely accessible across multiple platforms, offering affordances we know are necessary for productive teamwork, and which reflect authentic environments our learners will encounter in the virtual, asynchronous, project-based, collaborative workplace. One such solution is GitHub.

GitHub is an open-source collaborative environment widely used for software development. It is considered by its developers to be founded on social principles to foster collaboration (Whitaker, 2014) and is a good fit for the principles underpinning established knowledge building and trialogical learning educational design approaches.

From the perspective of the instructor and learner, it has multiple affordances for group work mediated by technology and incorporating both knowledge- and process-related activity. Each group has its own repository (repo) which is a mini-website with a range of tools for developing shared documents and communicating with team members. Each repo contains tools for making decisions about changes to the shared documents, which can contain rich text, images and hyperlinks, and whose iterative versions are saved and can be compared. Messages in the repo are visible to all team members, can be threaded and associated with documents and other messages or specific people, can contain the same rich content as documents, and can also have associated metadata such as labels, tags and status information. Current versions of all documents are easily accessible, as is data about individual participation and contributions. From the researcher's perspective , GitHub offers a single source of collaboration data that spans complex interactions over time during technology-mediated project-based group work as well as iterative changes to knowledge objects, which could be drawn on using a range of analysis methods.

However, there has been little research conducted on its use in educational settings, and less still on its potential as an environment for project-based collaborative work outside computer engineering. Those studies which have been done suggest it has potential for improving participation, supporting knowledge building, and enhancing grading fairness, and emphasise the need for further research and the sharing of pedagogical and practical insights (Feliciano et al., 2016; Zagalsky et al., 2015). This study will address the research gap in our understanding of the affordances of GitHub for evidence-based asynchronous collaboration learning design and research.

1.4. Research questions

The main aim of this study is to make a methodological contribution to research on collaborative project work design in higher education by investigating what kind of affordances are available in professional knowledge environments for the development of epistemic agency through knowledge co-creation, using the activity data of student teams working asynchronously on shared technology-mediated knowledge objects in GitHub to identify actions and interactions which are indicative of epistemic agency and which create new knowledge through changes to the shared knowledge object.

The first objective of this study is to contribute to the understanding of effective computer-supported collaboration learning design through an exploration of professional knowledge environment affordances and constraints for university student project-based group work.

The second objective of this study is to make a methodological contribution to CSCL research by investigating how the data from professional learning environments can be collected and analysed for research on collaborative knowledge co-creation.

To achieve these aims, the study will investigate:

1. **What kind of agency emerges when university students work on project-based tasks using professional knowledge environments?**
    i. **at individual level**
    ii. **at group level**
2. **How can the data generated by group work in professional knowledge environments be used for research on knowledge co-creation?**

This investigation explores the use of GitHub by three groups of students in a Master-level course at an Australian university focusing on instructional and other types of design and modelling. An embedded case study method is used to conduct a thematic analysis of all student actions and interactions available in GitHub, and classify them into epistemic and regulative dimensions. Following other studies on agency in project-based group work in higher education, it analyses the way in which epistemic and regulative agency manifested in each team at individual and collective levels. The results are used to construct a series of conjectures about each team’s way of working together. The analysis is then extended to identify how manifestations of agency produced improvements to shared knowledge objects, finding substantial differences between teams. The findings led to the development of an additional layer of classification imposed across both knowledge and process dimensions relating to the level of relational presence in communicative actions between team members. Distinct from the meaning specific to coaching, relational presence in this context refers to a meta-communicative layer in team messaging where interpersonal warmth and empathy is present. This study found an association between relational presence in communication and both epistemic and regulative agency, with all three associated with more new knowledge creation.

1.5. Significance

There is consistent and growing interest in research on designing collaborative situations that facilitate the development of self-organisation, systems thinking, communicative skills and the creation of new knowledge in technology-mediated settings. Where previous studies on agency have often used custom-built online environments and required resource-intensive data collection and analysis methods, this study explores how established analysis methods for observing individual and collective agency might interact with online activity log data within a free, Open Source collaboration platform. To my knowledge, this is the first study to take this approach to date. This is significant because the findings from this study can benefit not only situations that reflect the specific analytic parameters of this thesis, but those across the wider landscape of collaboration learning design and research methodology.

From a learning design perspective, the identification of existing agentic constructs within the data demonstrates that the GitHub environment has affordances which provide for its emergence. The trajectory view possible through GitHub's sequential activity logs allows investigation of actions and interactions that are associated with the development of epistemic agency, which can inform the design of collaborative environments and tasks. Iterative development of group work products can be observed in a way that captures the nature, frequency and content of individual contributions within the overall frame of group activity. This allows both real time and post hoc analysis of the unfolding knowledge object and the role each student has in its creation, potentially addressing concerns about equitable participation and assessment, while at the same time making higher-level collaborative processes visible.

From a research perspective, a single source of digitised data freely available to students, instructors and researchers can overcome some of the current infrastructuring and resourcing barriers to collaboration research. GitHub data is not constrained to the analytical procedure used in this study, and could usefully contribute to multiple other pedagogical strategies and research methods including developments in network analysis, learning analytics, and group awareness tools. The simple form of the data allows it to be shared widely between projects as it is in a consistent format regardless of the collaboration site. This has the potential to support collaboration design and research at scale; networked, online and beyond traditional boundaries.

1.6. Thesis overview

This chapter sets out the background to the study, its broader context, the research gaps that it addresses and rationale, and presents an outline of the following chapters.

The Literature Review chapter opens with a review of emerging workplace and educational practices, elaborating the rationale for the study. It then provides a background for the study through a discussion of how historical theoretical developments around 'learning' and 'knowledge' are relevant to this research. It elaborates on the specific theoretical framework for this study by reviewing the literature on collaborative learning and shared epistemic agency. The chapter discusses key challenges in CSCL research, before considering professional knowledge environments as a potential setting for project-based group work in higher education. The chapter also examines the affordances of computer-supported collaborative learning (CSCL) for the principles of knowledge building and trialogical learning, and the materialisation of ideas into concrete form, which together with a review of literature relating to the use of GitHub as a collaboration platform in higher education inform the method for the study. The chapter concludes with a summary of the research gap which this study will address.

The Theoretical Framework chapter further distils the Literature Review to define the theoretical perspectives, assumptions and frameworks that underpin this study.

The Methodology chapter explains the way in which the study was conducted. It sets out the study design, setting and participants, ethical and pedagogical considerations, data collection and analysis procedures. It discusses the choices that were made about which data should be included, what constituted actions and interactions, and how they should be described. It explains the way these actions and interactions were classified into a schema and provides examples of each type as well as those which were on the borderline. It details the processes by which individual and collective behaviours were analysed and the steps taken to improve reliability and trustworthiness of the findings.

The Results chapter reports the outcomes from this study. It opens with an overview of the study findings, before discussing in detail the ways in which agency could be observed in each team. It presents a set of conjectures about specific aspects of each team's collaboration, and evaluates these against secondary data sources to test their validity. The chapter then extends the findings to set out how shared epistemic agency could be observed in the different groups.

The Discussion chapter contributes to the knowledge field by considering the study findings in relation to the research questions and the Literature Review. It extends existing research by discussing the affordances of GitHub which might support designing for and reaching the development of agency in higher education project-based group work, as well as some limitations of using the platform and how those might be approached.

The Conclusions chapter summarises the research contributions, and their relevance in relation to designing trialogical tasks in higher education. Limitations of the study and suggestions for further research in relation to GitHub as an environment for computer-supported collaborative learning are considered.

The Appendices contain data extracts and other supplementary information.

This concludes the Introduction.

2. Literature Review

This Literature Review synthesises and critically analyses the literature most relevant to the design and implementation of strategies for group learning in higher education which facilitate the materialisation and collective improvement of knowledge through technology-mediated co-creation and iterative advancement of shared knowledge objects in a problem-based task over time. Section 2.1 reviews the evolving nature of globalised work and the need for higher education to design learning situations that equip our learners to participate in asynchronous collaborative processes in unstructured project-based teams in virtualised environments. Section 2.2 sets out the importance of social and distributed productive activity to the way in which we now conceptualise knowledge and learning. Section 2.3 compares the diverse terminologies across the collaborative learning field and discusses how the perspectives of constructivism and sociocultural theory shape approaches to group work. Section 2.4 introduces individual and shared epistemic agency and the pedagogical design strategies found to facilitate its emergence. Section 2.5 examines the support CSCL environments offer for research on and implementation of those pedagogical approaches and identification of episodes of agency. Section 2.6 explains some barriers to this research and implementation, and work in progress to overcome them. Section 2.7 elaborates on the potential for GitHub to support idea materialisation through collaborative modelling in settings designed within the framework of trialogical learning, as well as addressing some of the persistent challenges in higher education group work.

The chapter closes by articulating the research gaps, and discussing why an extension of collaboration research into low-overhead freely-available student-managed asynchronous environments might be both timely and useful.

2.1. Large-scale virtualisation of work and study

Teamwork was already virtualised and intercultural in many organisations and institutions before the COVID-19 pandemic, and recent events have made collaborating across borders and between disciplines an operating model that is likely to be maintained (Coade, 2021; Gourani, 2020). The move to virtual work, learning and teaching has been hailed as a "revolution"(Gourani, 2020) which will change the future of work by expanding teams beyond international borders (Gourani, 2020) and introduce flexible work even for those organisations traditionally resistant to remote arrangements (Coade, 2021; Gourani, 2020). American tech companies Microsoft, Facebook and Twitter have all made working from home a permanent option (BBC News, 2020), and Japanese company Fujitsu has launched a "work life shift" initiative offering flexible hours and locations as part of a suite of measures "shifting preexisting notions of "life" and "work" through digital innovation" (Fujitsu, 2020). While there are exceptions (Musk, 2022), this trend is continuing globally (Bernstien, 2022). But this 'revolution' is not as recent as it might seem. In 2004, a Special Issue of *CyberPsychology & Behavior* was devoted to papers presented on Learning and Understanding in Virtual Teams at the 2003 European Association for Research on Learning and Instruction symposium, and its talk of freedom from the "constraints of factory walls, national boundaries, and contiguous time zones" (Kirschner, 2004, p. 133) foreshadowed the complex variables of supporting collaboration in virtual learning environments, if not the years it would take for those environments and practices to become mainstream.

In Australia, virtualised work and study has only recently been facilitated by large-scale live videoconferencing activity supported by the National Broadband Network (NBN), which in 2020 added no-cost network capacity to mitigate the pressure and congestion caused by unprecedented demand (Australian Competition and Consumer Commission, 2020) as people worked from home during lockdowns. However, this is a relatively new development in collaboration generally, as we can see from the growth of webconferencing provider Zoom from 10 million users in December 2019 to 300 million in June 2020 (Iqbal, 2021).

A more sustained feature of both the workplace and higher education has been collaborative environments designed to foster productive ways of working together. Growth in that sector has been steadily increasing before the pandemic with the global education technology (ed tech) market estimated at USD$18.66 billion in 2019 (Li & Lalani, 2021) and the enterprise collaboration technology market at USD$36.24 billion in 2020 (Mordor Intelligence, 2022). The Gartner technology research company rates Workstream Collaboration Tools[1] as

[1] The workstream collaboration (WSC) market consists of products that deliver a conversational workspace based on a persistent group chat. Products in this market are primarily used to organize, coordinate, and execute outcome-driven teamwork such as that associated with the project- or process-related activities. Secondary uses can include ad hoc collaboration and community discussions Gartner. (2021g). *Workstream collaboration software reviews and ratings*. Retrieved 2021/09/20/, from https://www.gartner.com/reviews/market/workstream-collaboration Gartner. (2021g). *Workstream collaboration software reviews and ratings*. https://www.gartner.com/reviews/market/workstream-collaboration ..

medium-risk, with deployment complete for most large (Gartner, 2021a) and midsize enterprises in 2021 (Gartner, 2021b). By 2025, global investment in online learning is estimated to be USD$350 billion (Li & Lalani, 2021). Where institutions and instructors may have been reluctant to embrace the potential of collaboration for learning identified by researchers two decades ago, particularly where it is online, asynchronous, and over time, it is now both an essential strategy to accommodate remote working and learning and an important global market.

It is not just work that is changing. Our conceptualisations of learning and knowledge have also undergone a transformation.

2.2. Changes to how we conceptualise knowledge and learning

2.2.1. Knowledge in the mind

The nature of knowledge and knowing has been contested since Classical times. Contemporary epistemology looks back to Aristotle's Nicomachean Ethics, and the five states in which a soul can grasp the truth (Aristotle, ca. 350 B.C.E.ca. 350 B.C.E., bekker line 1139b), and we can see the continuing influence of Aristotle's ideas throughout the evolution of what we now call the Learning Sciences. Aristotle distinguishes between *epistêmê*, a cognitive state of the soul, akin to scientific knowledge about something, *technê*, which is concerned with skilful craft, *phronesis*, an intelligent and situated awareness, *sofia*, high-level wisdom combining *epistêmê* and *nous*, and *nous*, the awareness of unarticulated truth (Aristotle, ca. 350 B.C.E./1999, Book VI). While Aristotle's perspective understands knowledge to exist primary in mind through establishing a memory of an experience or event (Bloch, 2007; Saugstad, 2013), his view of learning as occurring in an authentic sensory experience in a practical situation establishing a later memory which will be recollected in context (Bloch, 2007; Saugstad, 2013) is consistent with contemporary perspectives on 'learning by doing' (Bereiter, 2002a; Saugstad, 2013), 'cognitive apprenticeship' (Brown et al., 1989) and 'situated' learning (Lave & Wenger, 1991; Saugstad, 2013). While generally concerned with knowledge in thought, Aristotelian ideas of technê and phronesis also encompass engaging in productional activity and applying appropriate knowledge in practice, and acquiring this knowledge through participation in authentic professional environments (Saugstad, 2013), with an emphasis on habituation (Bloch, 2007; Saugstad, 2013), ideas still relevant through the work of modern educational theorists.

In the first half of the twentieth century, John Dewey, potentially influenced by the Russian developments toward sociocultural theory (Prawat, 2000) discussed in Section 2.2.2 below, argued for a more humane approach to traditional autocratic schools on the basis that more democratic social arrangements resulted in a better human experience for a greater proportion of people (Dewey, 1997). In *Experience and Education,* his view of the importance of social factors in learning is evident:

> *In a word, we live from birth to death in a world of persons and things which in large measure is what it is because of what has been done and transmitted from previous human activities. When this fact is ignored, experience is treated as if it were something which goes on exclusively inside an individual's body and mind. It ought not to be necessary to say that experience does not occur in a vacuum. There are sources outside an individual which give rise to experience. It is constantly fed from these springs.*(Dewey, 1997, p. 15).

Dewey agreed with Aristotle on the benefits of experience (Dewey, 1903, 1997; Saugstad, 2013) cautioning against the duality inherent in knowledge gained through instruction disconnected from “actual conditions of life” (Dewey, 1997, p. 20). In Dewey’s view, ‘knowledge’ is framed in a similar way to *epistêmê,* and ‘intelligence’ akin to *sofia*, incorporating both knowledge about things and immediate observations, synthesised into a ‘judgement’, and the potential of education was to intelligently direct the “possibilities inherent in ordinary experience” (Dewey, 1997, p. 40) with an emphasis on the *praxis* of that observation, synthesis and application to future experience in everyday circumstances (Dewey, 1997). Dewey challenged traditional educational paradigms by proposing that instead of a simple transmission of cultural heritage (Bereiter & Scardamalia, 1993) (Aristotle’s view of knowledge waiting to be discovered by the learner), schools should use problem-solving as a way of integrating the learners’ experience and context with the subject matter through reflection (Dewey, 1997; Saugstad, 2013), leading to new ideas that then become the basis for further experience (Dewey, 1997). He believed traditional passive educational models limited the learning that would emerge from “easy and ready contact and communication with others” (Dewey, 1997, p. 26). These ideas around new knowledge creation through activity with others are the basis for contemporary pedagogies around convergent conceptual change through collaboration (Roschelle, 1992) and an important foundation in the Learning Sciences (Hoadley, 2018).

While his work centred on child development rather than schooling, Swiss psychologist Jean Piaget also recognised the importance of sociocultural settings, specifically signs, intellectual values and societal norms, which he considered to modify individual mental structures (Piaget, 2003). From a psychological rather than philosophical perspective, Piaget (1963) proposed that ‘intelligence’ in and of itself (*ipse intellectus*) (p. 2) on the one hand results from our capacity to organise thought rather than from experience, in its cognitive basis similar to Aristotle’s *epistêmê* and Dewey’s progressive organisation of ‘knowledge’ (Dewey, 1997). Piaget also viewed intelligence as dependent on habits and associations gathered a constant relationship with our environment at a sensorimotor as well as neurological level (Piaget, 1963), in a similar manner to both Aristotle’s and Dewey’s experience and habituation. That relationship results in ‘assimilation’ of environmental experience, where it fits into our “cycle of organisation” (Piaget, 1963, p. 6), or ‘accommodation’, in which the cycle is modified by the experience, within a mental organisational structure described as a *schema* (Piaget, 1963, p. 5). This possibility of new knowledge creation through generative intellectual ‘construction’ of an external reality in which we are active participants through this integration (Piaget, 1963) presupposes that knowledge is extensible, relational and personal, overcoming Aristotelian limitations about ‘truth’, aligning with Deweyan ideas about individual and contextual experiences, and consistent with many aspects of pedagogies in use today. While it can be argued that these mental processes also occur in relation to social experiences, thus having a social dimension, in Piaget’s view knowledge is still the product of, and situated within, an individual mind. This ‘cognitive’ approach complemented the ‘situated’ view, and both were disrupted by sociocultural theory.

2.2.2. Knowledge beyond the mind

Belarusian psychologist Lev Vygotsky saw us not only as active participants, but as creators of the reality which we inhabit (Vygotsky, 1978). Influenced by the work of Marx and Engels, Vygotsky (1978), Leont'ev (1978) and Luria (1971) developed what is now known as 'sociocultural theory' after travelling to Soviet Central Asia in the 1930s to observe the after-effects of the Russian Revolution. For them, the social construction of knowledge extended to the historical circumstances in which we live, and the tools that we use, with these actively modifying our psychological processes and cognitive activity and in turn being modified by them (Leont'ev, 1978; Luria, 1971; Vygotsky, 1978). These theorists believed that bourgeois psychology was "locked in the phenomenal [inner] world of consciousness and the images that constitute it" (Leont'ev, 1997, p. 42), contrasted with Vygostsky's "theory of process, of an active consciousness, a theory of consciousness that reveals the real life of man, not some imaginary mental life" (Leont'ev, 1997, pp. 44-45).

The paradigm shift introduced in sociocultural theory was the interpretation of human psychological processes as not only active, but mediated by relations with psychological social and cultural tools such as art, language, diagrams, and mathematical notation (Vygotsky, 1997). Where previously psychology felt people controlled themselves from the inside out, and social scientists believed the world controlled people from the outside in (Engeström, 1999), the implications of this theoretical breakthrough were that people could control themselves from the outside in (Vygotsky, 1978), using their higher psychological processes, through tools – including linguistic tools enabling participation in social and cultural processes – to change their consciousness. These ideas have become foundational to educational theory.

In their seminal chapter "Rethinking Learning", Bereiter and Scardamalia constructed a philosophy of learning and knowledge that drew on the situated, active, cognitive and sociocultural work of the theorists above, recognising learning as extending beyond an individual mind-as-container to include cultural practices and artefacts as well as mental states of knowing (Bereiter & Scardamalia, 1996). For example, understanding "Newton's dog" (Bereiter & Scardamalia, 1996, p. 478) as demonstrated by a capacity to act intelligently in respect to the dog and explain necessary aspects of it, along with the capacity to discern where that understanding is limited and a motivation to improve it, incorporates Aristotle's *phronesis*, Dewey's pragmatism, Piaget's *schema*, and the Russian sociocultural position because it is knowledge grounded in context and informed by prior experience, in contrast to theoretical knowledge that exists only as a mental model abstracted from the learner's world (Bereiter & Scardamalia, 1996). However, knowledge expressions that take a non-physical form such as mathematical models are important objects not only as applied academic content, but also as ideas that can be improved by building on them (Bereiter & Scardamalia, 1996). This work extended the conceptual definition of knowledge beyond the individual, and, in important ways, also beyond the human, in a re-imagining of cognition that was also occurring in philosophy.

2.2.3. Knowledge beyond the human

In *The Extended* Mind, Andy Clark and David Chalmers argue that our beliefs and therefore knowledge are co-constituted by our environment, including other people ('agents') (Clark & Chalmers, 1998). They discuss two versions of the same character "Otto", both of whom have a notebook to record necessary information in because they have memory loss, and in each notebook the address of a museum is recorded differently. In this case, the authors argue, each Otto has a different belief about the location of the museum and it is important from a knowledge perspective because when they use this 'knowledge' one Otto ends up where the museum isn't (Clark & Chalmers, 1998). This is significant from a learning perspective because of the role that 'knowledge' or 'belief' plays in our behaviour, and for an Otto, knowledge that exists outside the "skin and skull" (Clark & Chalmers, 1998, p. 18) is as real as that within it. While this might seem an improbable scenario mildly tangential to the discussion of how we conceptualise and facilitate the development of understanding in higher education, it is relevant because of the increasing role that non-human agents play in our lives and work, and the way in which digital repositories like the internet essentially function like large notebooks. If a non-human agent is making a decision based on the incorrect address contained in their notebook, the implementation of that decision will be no less real despite the address itself being inaccurate, just as human decisions may be implemented but based on inaccurate beliefs. Returning to the technology research by Gartner, Bots[2], Virtual Assistants[3] and a range

[2] A Bot is an automated program on a network (esp. the internet), often having features that mimic human reasoning and decision-making Oxford English Dictionary. *"Bot, n.5"*. Oxford University Press. https://www.oed.com/view/Entry/251280?rskey=ije532&result=5 Oxford English Dictionary. *"Bot, n.5"*. Oxford University Press. https://www.oed.com/view/Entry/251280?rskey=ije532&result=5 ..

[3] Virtual assistants (VAs) help users or enterprises with a set of tasks previously only made possible by humans. VAs use semantic and deep learning (such as deep neural networks [DNNs], natural language processing, prediction models, recommendations and personalization) to assist people or automate tasks. VAs listen to and observe behaviours, build and maintain data models, and predict and recommend actions. VAs can be deployed in several use cases, including virtual personal assistants, virtual customer assistants and virtual employee assistants.Gartner. (2021c). *Definition of virtual assistant (VA) - Gartner information technology glossary*. https://www.gartner.com/en/information-technology/glossary/virtual-assistant-va .Gartner. (2021c).

of service orchestration[4] assistance services are in pilot for most large (Gartner, 2021a) and midsize enterprises in 2021 (Gartner, 2021b). Instead of a notebook, our collective and extended knowledge is now held across multiple systems and architectures, and it is not only human minds that draw on this 'knowledge' to decide, for example, the protocols that a nuclear plant will follow if an earthquake is predicted (Woo, 2019), or whether you are resuscitated after a health event (Biller-Andorno et al., 2022), or if you will be granted a housing loan (Remolina, 2022). This imposes an additional dimension on knowledge; that it be interpretable not only by humans but also by machine intelligence.

The concept of knowledge that exists in distributed form across multiple locations has been the subject of theoretical consideration across philosophy and cybernetics as well as the social sciences. Knowledge as contained in distributed agents had been raised by (Vygotsky, 1978) as well as Marvin Minsky (Minsky, 1987), with the terms 'distributed cognition' (Donald, 2004; Hutchins, 2001) or 'distributed intelligence' (Fischer, 2006) developed to describe systems of both human and non-human agents, including technologies (Donald, 2004; Fischer, 2006; Hutchins, 1995, 2001) such as the power plant, resuscitation and financial systems mentioned above. Belgian cyberneticist Francis (Heylighen, 2014) connects these ideas to introduce a theory for the "Global Brain", the "distributed intelligence emerging from all people and machines as connected by the Internet." (Heylighen, 2014, p. 2). It is only through this distributed processing that we will be able to deal with complex problems, where the number of solution paths can extend to one trillion for a series of actions twelve steps long (Heylighen, 2014). Our distributed cognition systems have to be autonomous and self-organising (Donald, 2004; Fischer, 2006; Heylighen, 2014; Hutchins, 2001) because their dynamic complexity is beyond individual comprehension. Increasing the non-human capacity of Artificial Intelligence (AI) is likely to further abstract thinking and knowledge from individuals, magnifying existing inequities (Thomas, 2017), with a merging of humans and technology inevitable, and "the singularity" of AI exceeding the capacity of human intelligence less than a decade away (Kurzweil, 2017). This complexity is another driving force in educational research because it requires us to design for and operate in

Definition of virtual assistant (VA) - Gartner information technology glossary. https://www.gartner.com/en/information-technology/glossary/virtual-assistant-va ..

[4] Service orchestration applications, systems and platforms manage layers of virtual and physical resources that can be scaled and modified in real time.

learning situations which involve multiple human and non-human agents, sources and forms of knowledge.

2.2.4. Summary

Over the past two thousand years, we have changed our view of how people experience learning and knowledge from a set of cognitive inner processes to a networked continuum of social and cultural practices enabled and enhanced by non-human technologies who are also participants in these practices. When we consider how to understand what someone knows, for example, about database design or conceptions of infinity, we now know that knowledge to be experienced as meaning constructed by connections and relationships to their historical and cultural situation in a socio-technical world. The “knowledge” output of these processes extends beyond individual persons’ inner worlds to memory extensions such as a dictionary or shopping list, drawing or model, complex systems like mathematics or networks, and creative works such as art and music mirroring real world connections and complexity both psychologically and physiologically, in inter-related systems that are dynamic and responsive to feedback. The knowledge represented in these distributed systems operates on a continuum of abstraction from human thought, and requires representations that can be productively acted on by both people and machines in order to advance it. These systems include not only people, but also physical, digital and unquantifiable experiences of being. The design challenge for the learning sciences is to develop educational experiences which facilitate the joint development of new knowledge that transcends, includes and shapes these complex human and non-human systems.

2.3. Evolution of research on collaborative learning

2.3.1. Definitions and theoretical perspectives

This concept of ‘knowledge’ or ‘intelligence’ as developed and distributed among people and non-human systems is an important feature of modern educational theory (Bereiter & Scardamalia, 1996; Fischer, 2006). However, designing effective collaborative environments where this knowledge can be materialised and shared is complex. Direct comparison between research studies has been impeded by the various theoretical perspectives, settings and terminologies used to describe learning together (Almajed, 2015; Jeong et al., 2019), with Goodsell et al. (1992) describing the range of activities as comprising co-operative learning, problem-centred instruction, writing groups; peer teaching, discussion groups and seminars; and learning communities. More recently, we use "collaborative" (Goodyear & Retalis, 2010; Isohätälä et al., 2017; Järvelä & Hadwin, 2013; Järvelä et al., 2015; Malmberg et al., 2017; Panadero & Järvelä, 2015), "cooperative", "peer" or "small-group" learning (Almajed, 2015), "collaborative knowledge-building" (Goodyear & Ellis, 2007), "teamwork and collaboration" (Cunningham et al., 2016; Luca & Tarricone, 2001; Tyler & De George-Walker, 2010), "teamwork" (Cochrane et al., 2008; Richards & Bilgin, 2012; Tucker & Abbasi, 2016), "peer-driven interaction" (Reilly, 2016), "collaborative [group] learning" (Clear & Kassabova, 2005; Parkes, 2010; Pearce et al., 2007; Stacey, 2005), "group problem solving" (Chalmers, 2009), "group-work" (Tempone & Martin, 1999), "collaboration" (Ng, 2008), "collaborative work" (Limbu & Markauskaite, 2015), and "collaborative group work" (Norton, 2007) to describe experiences that are designed in order to facilitate learning through constructing knowledge with others. Broadly speaking, these processes are known as 'collaboration', "an umbrella term for a variety of educational approaches involving the joint intellectual effort by students, or students and teachers together" (Smith & MacGregor, 1992, p. 11). In 1999, Pierre Dillenbourg declined even to define 'collaborative learning', preferring to discuss "a situation in which two or more people learn or attempt to learn something together" (Dillenbourg, 1999, p. 1), which speaks to its multiple interpretations, rich variety of approaches, and the existentialist nature of this dynamic system process.

Within this broad scope, there is a significant body of research around collaboration in education. From between one and nine mentions per year of 'cooperative learning' in the early 1980s in the ERIC (Institute of Education Sciences, 2021) database (Smith et al., 1992), a search for 'collaborative learning OR cooperative learning' from the year 2020[5] returns 29,722 results (Institute of Education Sciences, 2021). However, the generalisability of studies is constrained both by the wide range of settings and the divergent theoretical perspectives that have informed them (Almajed, 2015; Dillenbourg, 1999; O'Donnell & Hmelo-Silver, 2013), with literature distributed across "social, cognitive, developmental, educational psychology, instructional design, the learning sciences, educational technology, sociocultural research, social psychology, sociology, and computer-supported collaborative

[5] This year was selected in preference to 2021 because of the disruption to research activity caused by the COVID-19 pandemic.

learning" (O'Donnell & Hmelo-Silver, 2013, p. 1). This has led to different views in relation to both quality and quantity of effective research on how people learn in groups. Some consider "the widespread and increasing use of cooperative learning is one of the great success stories in social and education psychology" (Johnson & Johnson, 2009, p. 365), or that "research on cooperative learning is one of the greatest success stories in the history of educational research" (Slavin, 1996, p. 43), with "an extraordinary number of field experiments of high methodological quality" (Slavin, 1996, p. 64), while others describe a lack of sufficient academic rigour or methodological quality (Almajed, 2015). While collaborative learning research may be somewhat scattered (O'Donnell & Hmelo-Silver, 2013), the Learning Sciences provides an interdisciplinary locus which embraces the complex systems nature of learning by integrating these diverse theoretical perspectives, innovating pedagogical approaches that make learning more productive, and designing methods that allow meaningful research to be undertaken in complex environments (Kolodner, 2018).

2.3.2. Constructivism and the sociocultural dimension of learning in group work

In the research on collaborative learning, while theoretical perspectives differ somewhat between the cognitive approach associated with Piaget, and the sociocultural view of learning associated with Vygotsky and Leont'ev (Cress & Kimmerle, 2018; Danish & Gresalfi, 2018), both have a 'constructionist' (Smith & MacGregor, 1992) or 'constructivist' (Roschelle, 1992) dimension (Cress & Kimmerle, 2018) that emphasises social activity in order to facilitate active construction of knowledge. A philosophy as well as a pedagogy (Stacey, 2005; Wilson, 1998), constructivism holds that through active and purposeful work new ideas are integrated meaningfully with the learners' different worlds (Bransford et al., 2000; Jonassen, 1991; Kirschner & Van Bruggen, 2004; Smith & MacGregor, 1992), and when this work takes place on authentic problem-based tasks instead of abstractions, learners are able to engage in useful interactions and conversations about them that lead to novel insights and solutions (Brown et al., 1989; Chan & Van Aalst, 2018; Cress & Kimmerle, 2018; Hmelo-Silver et al., 2018; Stacey, 2005).

The aim of group work is to create social interdependence so that the work of each learner is connected to that of the others (Johnson & Johnson, 1992, 1999, 2009; Slavin, 1996; Smith & MacGregor, 1992; Zhang et al., 2009). Learners negotiate using everyday interactional moves like turn-taking (Dillenbourg, 1999; Jonassen & Kwon, 2001; Roschelle, 1992), and these exchanges involve opinions and emotions as well as perceived intellectual objectivity (Järvelä et al., 2018; Polo et al., 2016; Smith & MacGregor, 1992). From a design point of view, the intention is to increase the number and complexity of active and purposeful, mutual, interdependent goal-oriented interactions, for example, participating in arguments (O'Donnell & Hmelo-Silver, 2013), listening to justification of opinions and solutions (Slavin, 1996), or disagreement (O'Donnell & Hmelo-Silver, 2013) leading to elaboration (Chinn & Clark, 2013). This results in more or different learning for everyone (Dillenbourg, 1999) through the interaction of multiple perspectives (Stacey, 2005), and facilitates the creation of solutions that could not be arrived at by one person alone (Johnson & Johnson, 1999).

However, there is no guarantee that this kind of learning will occur (Barron, 2003; Bereiter, 2002a; Dillenbourg, 1999; Järvelä et al., 2021; Slavin, 1990), no universally accepted method or measure for determining successful outcomes (Hmelo-Silver & Jeong, 2021a; Jeong & Hartley, 2018; Jeong et al., 2014), and often no purpose for the created knowledge object after its submission for assessment (Brown et al., 1989). Designing for collaboration both complicates and enriches the evaluation process (Smith & MacGregor, 1992), with constraints around both space in a physical classroom and time in both planning and execution of student work (Smith & MacGregor, 1992; Zhang, 2013).

Because of its foundation in constructivism and active production of knowledge, group work is frequently organised around defined tasks or problems (Dillenbourg, 1999; Hmelo-Silver, 2004; Hmelo-Silver et al., 2018; Jonassen & Kwon, 2001; Smith & MacGregor, 1992) whose investigation or resolution requires participation by all team members. But while the task is usually addressed by the group as a whole, learning outcomes are still essentially focused on individual knowledge gains (Cress & Kimmerle, 2018) with student work often assessed individually (Smith & MacGregor, 1992; Tan et al., 2021).

When we can overcome these barriers, the evidence shows that outcomes from collaborative learning contribute to the outcomes we intend for our graduates, as students develop more innovative and novel maps (Chi & Wylie, 2014) and mental models leading to shared understanding (Chi, 2009), develop deeper engagement, better listening skills and confidence in raising and responding to questions with respect and courtesy (Smith & MacGregor, 1992), improve their academic achievement (Jeong et al., 2019; Kollar et al., 2018) and self-efficacy

(Jeong et al., 2019), and increase their personal development and satisfaction with university (Astin, 1992; O'Donnell & Hmelo-Silver, 2013). Working with people of other abilities and cultural groups has been demonstrated to improve social acceptance, liking and respect among students (Slavin, 1990) even after the task is completed (Johnson & Johnson, 2009). Social engagement for learning can lead to better mental wellbeing (Johnson & Johnson, 1999, 2009), greater productivity, and academic achievement (Järvelä et al., 2018; Johnson & Johnson, 1999). Active participation by all team members in interactions that are not task-focused has been demonstrated to help overcome emotional challenges (Isohätälä et al., 2017), and more individual and group learning is associated with having social as well as performance goals (Panadero & Järvelä, 2015).

2.3.3. Summary

These findings demonstrate collaboration for learning is not only significant from a knowledge creation perspective, but also for individual and collective human development. Together with the need for university graduates to be equipped with intercultural, critical and teamwork skills, this shows the importance of developing learning design approaches for higher education which foster positive group work outcomes through active social engagement in authentic and purposeful tasks which provide for the mutual exchange of diverse perspectives.

2.4. Individual and shared epistemic agency

Substantial research into designing for collaboration drawing on these theoretical perspectives shows the wide range of factors that influence learner experiences and outcomes (Barron, 2000; Dillenbourg, 2002). Some can be designed directly, for example the reward or recognition available (O'Donnell & Hmelo-Silver, 2013; Slavin, 1996), the type of task (O'Donnell & Hmelo-Silver, 2013), and group size or composition (Cress et al., 2009; Rogat et al., 2013; Slavin, 1990) may be within instructor control. Others can be designed 'for' (Tchounikine, 2019), such as equality of interaction (Johnson & Johnson, 2009; Rogat et al., 2013), social cohesion (O'Donnell & Hmelo-Silver, 2013; Slavin, 1996), and the active and generative socio-cognitive dynamic called 'agency' (Barron, 2000; Damşa et al., 2010). This section of the Literature Review focuses on the principles of learning environment design that facilitate individual and collective epistemic agency, with a detailed discussion of the way epistemic agency is conceptualised theoretically for this study at Section 3.4.

While research continues to address these multiple strands through different theoretical and methodological approaches, there is general agreement on the association of improved learning outcomes with the development of agency, and also general agreement on two specific design settings within which agency is more likely to emerge. The first relates to the nature of the interaction between group members in relation to the shared task, and the second to the way in which the group operates to produce objects or artefacts that capture and advance their knowledge.

2.4.1. Individual and collective actions and interactions

Cooperative learning was not significantly distinguished from collaborative learning until the 1990s (Lehtinen et al., 1999), and is similar in its theoretical foundation, strengths and limitations. Where the distinction between 'cooperation' and 'collaboration' has occurred is around the concept of sharedness. In current educational settings both will involve peers working at around the same level toward a common goal, but the group members' negotiation of the processes, interactions and outputs they work on together will be different. In studies of group work, the distinction between forms of collaboration is the sharedness of the task object, and the way in which participants go beyond the normative social 'script' to resolve a problem (Engeström et al., 2015). For the educational researcher or practitioner, where this distinction might be observed is how tasks are performed, particularly where it comes to division of labour (Dillenbourg, 1999; Lehtinen et al., 1999). While from a practical point of view, some level of task division can occur even in true collaboration, Dillenbourg (1999) distinguishes between 'horizontal' and 'vertical' division (p. 8). Where horizontal division in a team might involve interwoven and interchangeable layers of meta-level and task-level work, vertical division is a fixed division of independent tasks that need not have reference to each other, and where such division is often made at the initiation of the project, with the latter typical of cooperative (Dillenbourg, 1999), or coordination (Engeström, 2008) designs.

This kind of division can occur in cooperative learning settings where the instructor may centre the task around a precisely structured problem (Zhang et al., 2009) with a known answer (Smith & MacGregor, 1992), and also participate in structuring the organisation of the group (Nedic et al., 2011; Zhang et al., 2009). For example, they may assign roles to ensure positive team behaviours (Johnson & Johnson, 1999; Smith & MacGregor, 1992) or play an active part in mediating team interactions (Zhang et al., 2009). Given that the top student concerns about teamwork are unequal contribution (Strauß & Rummel, 2021), individual differences and unfair assessment (Tucker & Abbasi, 2016), these instructor-led process supports are an understandable response, as is individual grading for group tasks (Smith & MacGregor, 1992), particularly when standardised testing is at stake (Scardamalia, 2002).

However, these sociocultural interactions between group members around the process of collaborative problem solving are of fundamental importance for our learners. Self-organised conversations around how to work together to solve a problem result in the development of important communicative metaskills (Dillenbourg, 1999; Johnson & Johnson, 1996; Muukkonen & Lakkala, 2009) at both individual and group level (Rogoff, 1998). This social justification of belief about how we think the world works and why we think that is a useful way of understanding it draws on more than cognitive resources and can create new paradigms of “perception, thought, feeling, and expression” (Smith & MacGregor, 1992, p. 11) because engaging each other in shared attention and creating some common ground is necessary even to disagree (Rogoff, 1998). Mutual regulation, negotiation and disagreement (Cress & Kimmerle, 2018; Jeong & Hartley, 2018), while uneasy for learners, generate extra cognitive mechanisms (Bransford et al., 2000; Dillenbourg, 1999; Johnson & Johnson, 1996) which can be inhibited by over-regulation by the instructor (Dillenbourg, 1999, 2002). Issues of power and equity (Gomez et al., 2018) and low levels of negotiation can privilege some kinds of knowledge over others, because without ‘abnormal discourse’ diverging from what everyone automatically agrees on as ‘rational’, the necessary creativity to break out of established canons of knowledge does not occur and challenges to established authority do not arise (Gomez et al., 2018; Smith & MacGregor, 1992).

Despite this, much of the research related to collaborative learning, and therefore likely much of the pedagogical implementation, has taken place in settings where the decisions about the teamwork have been made not by the team, but by the instructor (Reimann & Kay, 2010; Scardamalia, 2002). As a result, in groupwork situations where the collaboration is over-specified and becomes cooperation, there may be limited exchanges of worldviews, fewer communicative meta-skills developed, lower levels of cognitive resources engaged, and less potential for the development of new knowledge. When students can not bring their own ideas about what is important and meaningful to the work and the task, they are also less likely to develop either 'productive' (Schwartz & Lin, 2001) or 'epistemic' agency (Scardamalia, 2002).

While 'epistemic agency' has a specific contextual meaning in educational theory (Scardamalia, 2002), the philosophical construct is very similar. An epistemic agent has the capability to adapt their actions in order to adjust their belief state (for example, knowledge) in a situation, given an ideal standard for comparing the belief against, and a way of measuring the effect of their actions (for example, engaging in further inquiry) on that belief state (Reed, 2001). The 'agency' is the exercise of that capability, at whatever level it occurs. While the philosophical construct also deals with ideas of virtue and character (Reed, 2001), in collaborative learning research the term describes deliberate efforts by students to develop understanding that go beyond simply expecting the instructor to provide the solutions (Chan, 2013; Scardamalia, 2002; van Aalst & Chan, 2007). Both the philosophical and the pedagogical conceptualisations view this in terms of cognitive 'responsibility' (Reed, 2001; Scardamalia, 2002) for knowledge work (Scardamalia, 2002). Employers view this in terms of 'engagement' and it is an essential precondition for organisational success in the knowledge economy (Atapattu & Huybers, 2021; Scardamalia, 2002). It is clear that the development of this capability for intentional knowledge building is an important outcome from instruction (Chan & Van Aalst, 2018; Muukkonen et al., 2005; Scardamalia & Bereiter, 2010), and it has been identified as an emerging research trend for three decades (Ludvigsen & Steier, 2019; Tan et al., 2021).

Significant investment has been made in designing learning and teaching principles and environments to support 'true' collaboration and development of epistemic agency, notably within the pedagogical framework of knowledge building (Scardamalia, 2002; Scardamalia & Bereiter, 1994, 2010, 2021; Tan et al., 2021), and its underpinning networked support systems CSILE, Knowledge Forum® (Scardamalia & Bereiter, 2010, 2021; Tan et al., 2021) and other knowledge building environments (KBEs) (Hong et al., 2019; Yang et al., 2019). Knowledge building is an educational approach developed over the last four decades from research into learner agency and intentional efforts to construct understanding beyond simple task completion (Chan, 2013). Its origins reflect the changes to how we conceptualise knowledge discussed in Section 2.2, with (Bereiter & Scardamalia, 1996) articulating the need in education to move beyond the 'mind as container' metaphor that viewed changes in subjective belief as 'learning'. Knowledge "treatable as an object" (Bereiter & Scardamalia, 1996, p. 474) is the output of the knowledge work that our societies – and economies – are now engaged in (Bereiter, 2002a), and the 'building' work is activity directed toward these objects; their creation, revision and evaluation (Bereiter & Scardamalia, 1996). The knowledge that is constructed is collective property that extends beyond individual understanding (Bereiter, 2002b; Scardamalia & Bereiter, 2010), and the building process part of a culture whose primary purpose is to take collective cognitive responsibility (Scardamalia, 2002) for collaboratively advancing and continually developing that construction (Scardamalia & Bereiter, 2006), bridging individual and collective awareness in a way that is not achieved through simple cooperation (Bereiter, 2002b).

This focus on epistemic agency at individual and collective levels overcomes some of the limitations of other learning theories. For example, in problem- or project-based learning, task design is based in a problem or question, with the aim of scaffolding the collaborative process, generating discussion, and constructing knowledge (Bereiter, 2002b; Chan, 2013). However, in some settings, the instructor may define the project, or the solution to the problem may already be known, leading to lower levels of question-driven inquiry (Bereiter, 2002b), less mutuality (Zhang et al., 2009), limiting the co-creation of new ideas (Baker et al., 2021). As in the educational model criticised by Dewey, learning can be individual remembering and retelling, but agentic knowledge transformation requires a public restructuring of what is known through productional activity (Chan, 2013; Chan & Van Aalst, 2018). While in many conceptions of learning the traditional measure is attitudinal change in relation to knowledge that is already known, like Aristotle's truths waiting to be apprehended, knowledge building seeks to improve existing ideas in an open-ended process of self-directed negotiation and inquiry (Chan, 2013; Chan & Van Aalst, 2018). Where a traditional classroom discussion may involve the instructor taking responsibility for the manner of learner participation and the evaluation of learner insights (Scardamalia, 2002; Scardamalia & Bereiter, 1994; Zhang et al., 2009), a knowledge building discussion is a setting where the students and instructors work together on defining the task and the way in which it unfolds (Chan, 2013; Chan & Van Aalst, 2018), with learners monitoring and assessing their own progress in knowledge advancement (Chan & Van Aalst, 2018; Scardamalia & Bereiter, 2021), developing individual and shared epistemic agency.

This work has shown that by redesigning tasks to place open-ended student ideas at centre of a self-managing sociotechnical system, students develop more agency, and they are more likely to take more individual – and collective – cognitive responsibility in these learning situations, leading to more knowledge advancement (Scardamalia, 2002; Scardamalia & Bereiter, 2021; Scardamalia et al., 2012; Tan et al., 2021). Using knowledge building principles in educational design can result in increased student agency, as well as higher levels of activity, greater content mastery, deeper inquiry, more advanced knowledge objects, better wellbeing, and socialisation within a culture of authentic knowledge creation (Scardamalia & Bereiter, 2021). Because of this, knowledge building provides an optimal framework for designing learning experiences that equip students to develop individual and shared epistemic agency.

2.4.2. Individual and collective process of creating knowledge objects

Knowledge building and knowledge creation can be seen as synonymous (Scardamalia, 2002), and will be treated as such in this study. However, a branch of knowledge building research has developed a knowledge creation framework described as 'trialogical learning' (Paavola & Hakkarainen, 2005) of specific relevance to this research. There is significant convergence between the perspectives; knowledge building considers itself concerned with creating knowledge (Bereiter, 2002b; Bereiter & Scardamalia, 1996; Scardamalia & Bereiter, 2006, 2010), and (Paavola & Hakkarainen, 2005) considers knowledge building an essential aspect of the knowledge creation process. Generating new ideas and conceptual knowledge through the provision of supporting social structures and collaborative processes is consistent with both approaches (Paavola & Hakkarainen, 2005; Scardamalia, 2002; Scardamalia & Bereiter, 2010), as is the importance of networked software environments for collaboration (Paavola & Hakkarainen, 2005; Scardamalia, 2002; Scardamalia & Bereiter, 2010, 2021).

Where the frameworks diverge is in Paavola and Hakkarainen's expansion of the original knowledge building model by incorporating elements of Engeström's (Engeström, 1987) focus on actively creating new contexts and Nonaka & Takeuchi's (Nonaka & Takeuchi, 1995) focus on actively creating new knowledge through the materialisation of tacit knowledge, and – specifically – those interactions being mediated through the systematic technology-enabled development of knowledge objects (Paavola & Hakkarainen, 2005, 2014). Individual tacit knowledge is externalised dialogically through negotiation and discussion, with the difference from other collaborative methods being the materialisation of that knowledge into shared, concrete, knowledge objects which are then further modified not only by one person, but by the efforts of the group (Paavola & Hakkarainen, 2009), and used to represent, organise and advance group processes as well as the group's knowledge (Paavola & Hakkarainen, 2005, 2014). The learning process occurs through the construction of an understanding of the characteristics of the final version and the means by which it is produced in the course of that activity (Paavola & Hakkarainen, 2009).

The interactions are described as 'trialogical' to reflect the instrumental nature of the artefact as a mediator through which the people and the elements of the learning environment connect (Paavola & Hakkarainen, 2005) while engaging in an authentic task and progressively transforming both the artefact and their social practices to develop collaborative ways of working together (Hakkarainen, 2009; Paavola & Hakkarainen, 2014; Paavola et al., 2004). An 'object' in this sense can encompass a topic or goal as well as a document, plan or model (Paavola et al., 2011) and in this thesis, 'knowledge object', 'artefact' and 'document'[6] are used interchangeably to refer to digital or material resources for or products of group work in educational settings. Each object become a socio-material entity within the collaboration which not only represents the state of the knowledge at different times throughout the process but also influences the group's motivation to complete it, therefore eliciting epistemic agency (Paavola & Hakkarainen, 2021). The additional dimension within the trialogical knowledge creation metaphor is illustrated by the grey shaded circle in the diagram at Figure 1 below (Paavola & Hakkarainen, 2009), showing the instrument-mediated iterative development of both artefacts and practices within the overall structure of a knowledge-building community based on constructivist principles.

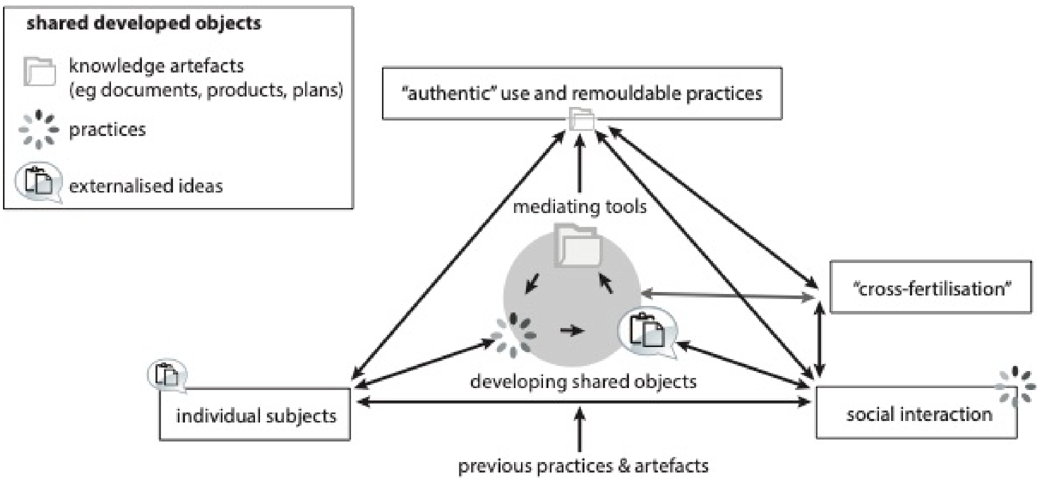

Figure 1: Model of the trialogical knowledge creation design principles adapted from (Paavola et al., 2012).

6 In this study, 'models', 'diagrams', 'code', 'narratives', and the assemblage of them individual group repos are all considered sub-types of 'knowledge object'

These collaboration environments are also an important source of analytic feedback for both students and instructors, and should have information about the group's knowledge state and its change over time in a form that is usable, transparent and visualised clearly (Chen & Zhang, 2016; Scardamalia & Bereiter, 2021; Tan et al., 2021) to support individual and collective epistemic agency (Chen & Zhang, 2016). This requires the object structure to have a stable enough form for the nature of extent of changes to be readily accessible to human and machine comparison. To go further and identify agency requires a classification framework, and criteria for the system (or researcher) to identify how to classify agentic activity.

But in the same way it is challenging to develop collective learner agency (Tan et al., 2021) it is also challenging to observe and analyse it (Damşa & Ludvigsen, 2016), and more research is needed to understand the combination of individual and collective agency in knowledge building settings, and the trajectories of knowledge object co-construction (Baker et al., 2021; Cress & Kimmerle, 2018; Damşa, 2014; Damşa et al., 2010; Damşa & Ludvigsen, 2016; Paavola & Hakkarainen, 2021; Wise & Schwarz, 2017).

One series of research studies has made significant advances in developing a framework for observing the emergence of shared epistemic agency through analysis of group interactions and knowledge object transformation over time (Damşa, 2014; Damşa et al., 2010; Damşa & Ludvigsen, 2016). (Damşa, 2014; Damşa & Andriessen, 2012; Damşa et al., 2010) has drawn on the knowledge creation perspective, and the resources of the intentionally-designed collaboration environments, to provide an empirically-founded description of this construct beyond the boundary of the individual in three studies based in higher education group work. Developments in understanding epistemic agency are significant because of the wide recognition across the Learning Sciences that the purpose of instruction has shifted from content knowledge to metaskills and epistemological changes such as self-regulation, metacognition, and collaborative skills (Muukkonen & Lakkala, 2009; Muukkonen et al., 2005) and the creation of new knowledge in order to solve complex problems (Goodyear & Zenios, 2007; Ludvigsen & Steier, 2019; Tan et al., 2021; Yoon, 2018).

In their review of studies of epistemic agency in collaborative educational contexts, Damşa et al. (2010) identified four types of knowledge-related (epistemic) actions: collecting information, exchanging insights, structuring ideas and participating in epistemic discourse

(Damşa et al., 2010). They also identified a second category of activity which was present in these situations. Three types of process-related (regulative) actions were identified: planning and goal setting, coordinating and monitoring activities, and using relational strategies to ensure convergence of ideas (Damşa et al., 2010). In this and later studies, the results demonstrated that both these dimensions are necessary for groups to sustain productive object-oriented collaborations that result in new knowledge creation, and that groups with a higher degree of agency create more advanced versions of knowledge objects (Damşa, 2014; Damşa & Andriessen, 2012; Damşa et al., 2010).

While all these activities can be done at an individual level, these studies also found that epistemic agency could emerge at a higher level, where a combination of actions jointly performed by group members moves the knowledge work forward in a way that could not be achieved by individual effort alone (Damşa, 2014; Damşa et al., 2010). This conceptual theoretical shift toward sharedness of the agency around group learning shows the increasing recognition of the sociocultural model of learning discussed earlier in relation to collaboration and knowledge creation, and the potential for knowledge-focused productional action to be planned and implemented at a group level (Damşa, 2014; Damşa & Andriessen, 2012). However, developing collective agentic behaviour is challenging because of the complex and dynamic nature of the collective system itself (Tan et al., 2021), and even when environments are intentionally designed to facilitate collaborative work on shared knowledge objects, student groups do not automatically work productively together (Damşa et al., 2010).

What was shown to be essential, and a condition for the emergence of shared epistemic agency, is creating awareness of a lack of knowledge or of problematic situations (Damşa et al., 2010). This by itself is not sufficient; to ensure good knowledge creation practices a pattern of activity should follow in which reflection on future courses of action occurs, then those actions are subsequently undertaken collectively, which in turn leads to knowledge object development (Damşa et al., 2010). Because shared epistemic agency does not reside within individual minds, and only emerges during active participation in knowledge co-construction, the role of the knowledge object(s) is central to the activity, and to the concept (Damşa, 2014; Damşa et al., 2010). While not explicitly expressed as 'trialogical', these studies drew on the object-oriented knowledge creation work by Paavola and Hakkarainen (Paavola & Hakkarainen, 2005) as a theoretical foundation.

In their initial study, two groups of university students in an educational design course worked on a collaborative project whose aim was to engage in an authentic open-ended design task with a real-world client (Damşa et al., 2010). The researchers identified agentic actions in both groups, but observed that epistemic actions occurred more in one than the other, and that in combination with regulative actions these led to the materialisation of new knowledge in shared knowledge objects (Damşa et al., 2010). Damşa and Andriessen (2012) also observed differences in the way shared epistemic agency manifested between groups, reinforcing their initial theory that it is a complex and emergent process, but also finding that a collaborative, long-term task was important for the type of strategies the students developed in support of it (Damşa & Andriessen, 2012). The collaborative project-based task required both epistemic and regulative activities that were beneficial for both advancing the knowledge object and working together (Damşa & Andriessen, 2012). In a very similar study, Damşa (2014) found that in complex projects like these, the materialisation of knowledge into objects helps with the continuity of the process and the progressive co-construction of the group's knowledge.

In these cases, data collection and analysis was conducted qualitatively, using discussion protocols, semi-structured interviews (Damşa, 2014; Damşa & Andriessen, 2012; Damşa et al., 2010), observations, open-ended questionnaires, written documents (Damşa & Andriessen, 2012), field notes (Damşa, 2014), emails, intermediate and final task products (Damşa, 2014; Damşa et al., 2010). Although the research focus varied, in each case the analytic perspective was longitudinal (Damşa, 2014; Damşa & Andriessen, 2012; Damşa et al., 2010), and the dataset viewed through an interpretative lens inferring learner intentions through observable behaviours that might cross boundaries between different data types, for example, a discussion that led to a change to a document. For (Damşa & Andriessen, 2012; Damşa et al., 2010) the unit of analysis was not the individual input but the group as a whole.

Damşa (2014) went further than the previous two studies in their investigation of the processes that operate to produce shared epistemic agency in relation to (shared) knowledge objects, conceptualising the phenomena as 'productive interactions'. These are contextual sequences of collaborative actions that move the knowledge object from one state to another (Damşa, 2014). In this study, the unit of analysis shifted to reflect the layers of individual and joint interacting processes, with verbal actions coded at the individual level based on the epistemic and regulative dimensions from (Damşa et al., 2010), but contextualised within the collective discourse as episodes within themes that were relatively bounded (Damşa, 2014). This group interaction layer was considered in relation to a second layer which combined analysis of interactions with consequent changes in the knowledge objects, and a third layer which identified regular sequences in the second layer as indications of shared epistemic agency (Damşa, 2014). The relationship between these aspects is illustrated at Figure 2.

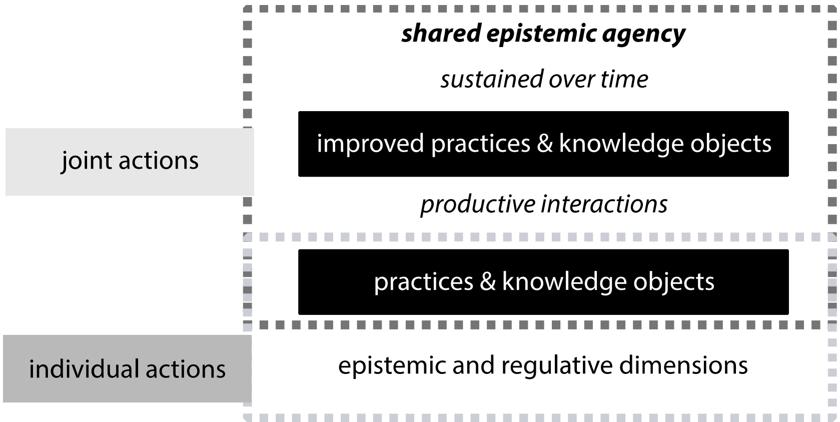

Figure 2: Layers of action and interaction as the basis of analysis for shared epistemic agency.

This allowed for some observations to be made about the characteristics of interactions at group level based on individual actions at the first level and shared knowledge objects at the second level (Damşa, 2014). Their previous findings about the balance of epistemic and regulative interactions leading to materialisation of new knowledge in their shared object being associated with higher quality outcomes were once again reinforced, with a new finding – the frequency of these interactions was also important (Damşa, 2014).

These results were confirmed in a subsequent study (Damşa & Ludvigsen, 2016), which followed their previous studies in that data collection and analysis was conducted qualitatively, using discussion protocols, semi-structured interviews, emails, meeting notes, reflective questionnaires, comments, intermediate and final task products. While this study drew on the idea of productive interactions from Damşa (2014) with group interactions coded using the epistemic and regulative dimensions from (Damşa et al., 2010), it focused on specific examples of idea uptake for the key concepts in the knowledge objects and interaction sequences, again finding differences between the student groups in the way they collectively engaged in the strategic elaboration of knowledge and advancement of the development of their shared knowledge objects (Damşa & Ludvigsen, 2016).

2.4.3. Summary

The results from these studies are consistent. Within the same cohorts, doing the same tasks, using the same collaboration environments, some student groups did not progress past collecting information and processing it individually, where others were able to engage in sharing, negotiating and materialising new knowledge in iterative versions of high-quality knowledge objects. This indicates that agency at individual and collective levels is a dynamic construct that has been associated with the frequency and productivity of shared interactions. This suggests that it may be possible to facilitate the development of agency by providing support for frequent and productive interactions. It also demonstrates that both individual and shared epistemic agency are observable within the data generated by university group work.

2.5. CSCL environments for knowledge creation

Because of the capacity for digital technology to transform ideas into tangible representations, CSCL is tightly interwoven with both the theory of knowledge building and the knowledge creation metaphor in time (Scardamalia & Bereiter, 2021; Stahl, 2015) and in practice (Paavola & Hakkarainen, 2005, 2009, 2014, 2021; Paavola et al., 2004; Scardamalia, 2002, 2004; Scardamalia & Bereiter, 1994, 2006, 2010, 2021). In a recent review of CSCL literature on STEM (Science, Technology, Engineering and Mathematics) education published between 2005-2014, ‘knowledge building’ comprised the largest research topic, and around half the body of research identified used constructivist and sociocultural theoretical frameworks (Jeong et al., 2019). Initially developed by Marlene Scardamalia and Carl Bereiter to support active knowledge building processes (Scardamalia & Bereiter, 2010; Scardamalia et al., 1989), the computer-based collaborative platform CSILE (Computer Supported Intentional Learning Environments) and its subsequent upgrade Knowledge Forum have been considered the “most extensive and influential” (Stahl, 2015, p. 339) effort to influence school education through CSCL. While the software was released at consumer level by Apple Computer in 1993 as a “Collaborative Learning Product” (Scardamalia, 2004, p. 1), its principal impact has been in the field of educational research (Stahl, 2015), and particularly on ideas around knowledge building

(Scardamalia, 2004; Scardamalia & Bereiter, 2010, 2021). Instead of the administrative affordances we associate with modern Learning Management Systems (LMSs), the focus of CSILE and other knowledge-building environments is the socio-technical aspect of collaboration, comprising a community knowledge space where notes containing theories, models or ideas can be linked or built on (Scardamalia, 2004; Scardamalia & Bereiter, 2010, 2021; Scardamalia et al., 1989). This allows the different knowledge objects to undergo the public restructuring necessary to generate novel ideas and theories, with multiple persistent representations supporting inquiry over time.

2.5.1. CSILE, Knowledge Forum and the Knowledge Practices Environment

Kai Hakkarainen credits working with CSILE at the University of Toronto as providing the insights that led to the development of the knowledge creation metaphor (Hakkarainen, 2009), and those observations are still at the centre of CSCL design from the sociocultural perspective: materialisation of ideas into artefacts is essential to have an account of understanding that can be built on; these artefacts constitute extensions of our memory and operate as tools that can help guide inquiry; and an environment in which agentic activity such as organising, transforming and sharing not only the artefacts themselves but the social practices for doing so are all necessary to develop a successful knowledge culture (Hakkarainen, 2009). These principles are reflected in the design aims of the Knowledge-Practices Laboratory (KP-Lab) (Hakkarainen et al., 2006; Paavola et al., 2011) to develop technological support for trialogical learning by facilitating those activities (Paavola & Hakkarainen, 2009; Paavola et al., 2011) as opposed to institutional systems designed to facilitate the administrative functions of the instructor, with ad hoc tools often embedded for collaboration in a ‘bricolage’ (Rosé et al., 2019). While other platforms for collaboration founded on sociocultural theory such as the Web-Based Inquiry Science Environment (WISE) (Linn et al., 2003; Slotta, 2013), Virtual Math Teams (Stahl, 2009, 2017), and the Quest Atlantis Multi-User Virtual Environment (Barab et al., 2007; Tüzün et al., 2019) are also designed to support shared inquiry, the principles underpinning knowledge building make the pedagogical approach and its designed networked collaboration environments extensible beyond disciplines and beyond educational settings (Scardamalia & Bereiter, 2014a).

This research using CSCL environments to support knowledge building and knowledge creation has provided some consistent design principles for enabling agency through trialogical learning affordances: task and environment together should support frequent and productive object-oriented activities that integrate individual and group participation over time; these should particularly focus on open-ended authentic complex problems, and the flexible tools provided should specifically facilitate the externalisation and materialisation of ideas, concepts and under-articulated or tacit knowledge so that they can be advanced by collective efforts (Hakkarainen et al., 2006; Paavola & Hakkarainen, 2014; Paavola et al., 2011). These materialisations function as external memory fields (Hakkarainen, 2009; Hakkarainen et al., 2011; Paavola & Hakkarainen, 2014; Ritella & Hakkarainen, 2012), part of extended cognition (Clark, 2003, 2017; Clark & Chalmers, 1998) and by further extension part of mind. They are significant because as intermediate objects reflecting the group's state of knowledge compared to the model object they provide a focus for the collaboration, acting as "stepping stones" (Paavola & Hakkarainen, 2014, p. 244; Ritella & Hakkarainen, 2012, p. 12) for iterative, visible, knowledge advancement. They are subtle because the components of them start out inside individual consciousness and must be elicited and expressed in order to be materialised, represented and shared. The mechanism by which this non-explicit knowledge is mobilised in groups is an important aspect of knowledge creation (Batatia et al., 2012; Paavola & Hakkarainen, 2005).

As the work by Damşa and others discussed above focused on the emergence of shared epistemic agency (Damşa, 2014; Damşa, 2014; Damşa & Andriessen, 2012; Damşa et al., 2010), they do not make specific report of the process by which the groups materialised their ideas. Given the data analysed it is likely they mostly had synchronous meetings in which they verbalised their thoughts to a fairly coherent stage and then created iterative drafts of documents using a word processor-type application, using shared notes, discussion boards and emails for interim communications. For example, the exchange below occurs at the end of a conversation where a series of concrete suggestions have been made in relation to the features of an intermediate object representing the learning goals for the project they are doing, indicating ideas that are fairly fully formed and expressed in a way that is easily understood by the other participants:

10. Alex: *But you could, for example, use a map and indicate with arrows and images* the landscape in each area; and a short description of the savanna climate, for example.
11. Mel: *Shall I start writing that down, we'll need this to make the goals setup?* (Damşa et al., 2010, p. 171, emphasis in original)

This is of course the way in which most workplaces conduct business, student groups operate and is a routine and widely accepted sociocultural practice. Writing as a technology that allows humans to extend their cognitive architecture is the "principal vehicle of epistemic mediation" (Hakkarainen et al., 2011, p. 3)(p3) and plays a crucial role in the materialisation of thoughts to the external artefacts (Hakkarainen et al., 2011) that can then be shared and advanced. However, verbal communication in natural language is constrained in its capacity to reflect ideas that contain complex information, layers, or relationships, particularly when those ideas are incomplete.

As the knowledge creation approach emphasises the role of the technological environment in epistemic mediation (Hakkarainen et al., 2006; Paavola et al., 2011) and the mobilisation of tacit knowledge (Paavola & Hakkarainen, 2005), the Knowledge Practices Environment (KPE) aimed to support modelling, sketching and testing knowledge objects (Paavola et al., 2011) as well as providing more typical support for object-oriented collaboration; an online space for artefacts to be organised, versioned and attached to comments, and for team processes to be organised through a calendar, messaging tools and task list. It moved beyond text-based knowledge materialisation by including both a shared whiteboard-type drawing tool, and a visual modelling editor (Lakkala et al., 2010; Metropolia University of Applied Sciences, 2021). An overview of the environment from the KP-Lab project report is at Figure 3, with the drawing tool (*Piirokset*) and modelling tool (*Visuaalinen mallinnus ja mallinnuskielet*) in the top right quadrant.

The capacity for learners to work with multiple conceptual models was articulated in the high-level design requirements for the KP-Lab as an enabler of semantic negotiations (Lakkala et al., 2010), however this might be under-stating their potential both for learning and for collaboration.

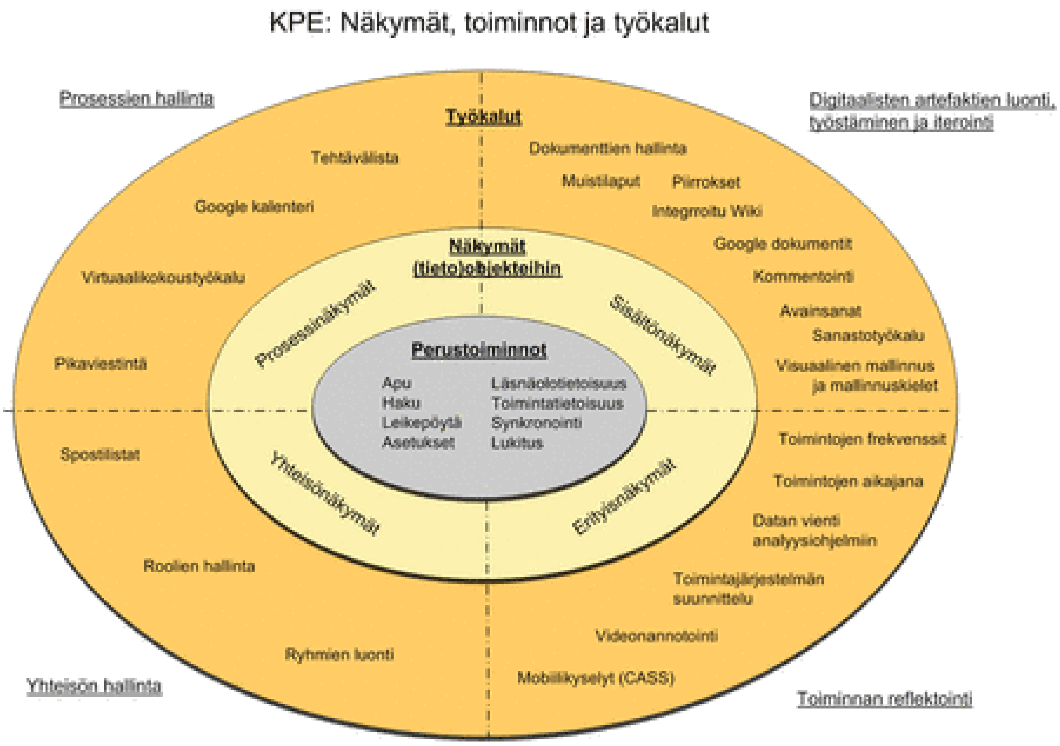

Figure 3: Illustration of the KPE and the different tools supporting the dimensions of mediation it is designed to facilitate (Metropolia University of Applied Sciences, 2021).

2.5.2. Collaborative modelling / Group model building

Outside formal education, collaborative modelling (or group model building [GMB], or group modelling) is well-established as a process to elicit and share mental models (Vennix et al., 1996) while solving complex social problems, such as health care (Andersen & Richardson, 1997; Richardson & Andersen, 1995), environmental management (Stave, 2002) and other ‘messy’ problems (Vennix, 1999). Similar in some ways to our cognitive goals for collaborative learning, GMB aims to “help individual participants gain more insight into the structure and behaviour of a system” (Andersen et al., 1997, pp. 188-190) and generate a “change of attitude” toward a proposal (p. 191), although neither of those have been definitely shown to occur. More like our social goals for collaborative learning, GMB has systemic characteristics, often with a high-level objective such as social or organisational process change (Rouwette & Vennix, 2006; Vennix, 1999; Zagonel, 2002) interrelated with group goals of mental model alignment, creating agreement and consensus, and generating commitment to a decision (Andersen et al., 1997; Rouwette & Vennix, 2006; Vennix et al., 1996; Zagonel, 2002). It has been used for problem structuring where there is not even agreement on whether there is a problem (Vennix, 1999). Through the materialisation of implicit assumptions and tacit knowledge, group modelling can make visible not only what participants think is occurring in a system but how they think these things are related and what is causing them (Vennix, 1999) even if the participants themselves did not know until then. Group modelling is considered particularly valuable for interdisciplinary work because of its capacity to create a common context for the different elements, objectives and methods introduced by each discipline to the shared purpose (Luna‐Reyes et al., 2019). Importantly, models are not just human-readable, but also discernible by computerised systems, meaning manipulation of a great deal of complexity can be performed in a short period of time, and the outcome reported, represented and shared as data which can then be used as input for the same, or another, model.

Constructing shared models can also overcome the problem that individuals often have only partial or fragmented understanding complex situations (Vennix, 1999) such as when multiple stakeholders are involved (Zagonel, 2002), when managers have a limited view of the organisational whole (Vennix, 1999) or when there are differing opinions about what governs system behaviour (Zagonel, 2002). Their capacity to condense a lot of complexity into a relatively small space (Morecroft, 2007) and make the central features of a system explicit and visible (Linn et al., 2018) facilitates this 'systems thinking' view encompassing causal relationships between the parts, their direction and impact, illustrating how the solution will affect the problem or goal over time (Morecroft, 2007), both explanatory and predictive in nature (Linn et al., 2018). By operating as an external memory field and manipulable knowledge objects, models can mitigate the limitations of individual cognitive and perceptive processes (Vennix et al., 1996), and foreground the "multiple realities" (Vennix, 1999; Vennix et al., 1996) which need to be made visible within the system of inquiry in order for change to occur.

While group model building has evolved to take advantage of technological affordances, the range of stakeholders concerned and the lack of modelling experience they often have means a specialist facilitator and/or modeller who does not have domain knowledge and is not a part of the system does the actual modelling (Andersen & Richardson, 1997; Andersen et al., 1997; Hoppenbrouwers & van Stokkum, 2011; Richardson & Andersen, 1995; Richardson & Andersen, 2010; Vennix, 1999; Vennix et al., 1996), which might explain why evidence of conceptual change for participants is not yet robust. Designed workshops are resource-intensive and time-consuming (Andersen & Richardson, 1997; Hoppenbrouwers & van Stokkum, 2011; Richardson & Andersen, 2010; Vennix et al., 1996), and have traditionally required a large number of experts to meet face to face at least once (Andersen & Richardson, 1997; Hoppenbrouwers &

van Stokkum, 2011; Richardson & Andersen, 2010; Vennix et al., 1996). Even with this support, there are still concerns about who contributes what to the solution (Vennix et al., 1996), a similar issue to student attitudes about group work.

With the growing complexity of systems and organisations, and more collaboration between different types of knowledge workers, group modelling has become increasingly important and the field of practice and research has developed substantially since its introduction in the 1970s (Renger et al., 2008). With the growth of freely available online meeting and modelling tools, another barrier to its implementation has been removed.

2.5.3. The potential for collaborative modelling in trialogical learning

In organisations, the models that are constructed typically fall into what (Zagonel, 2002) has dichotomised as either a 'map' or 'microworld' representing a fact-driven reality, or a 'boundary object' reflecting a socially-constructed understanding of a system as the group perceives it (Zagonel, 2002). While Zagonel (2002) argues that in GMB a model should move from subjective boundary object to objective microworld in order to reach a clear problem definition, their recognition of the instrumentality of modelling in the consensual and political value dimensions of a group shows a tight alignment with the sociocultural perspective that is foundational to trialogical learning and knowledge creation.

Looking at Figure 4, which illustrates the understanding of GMB boundary objects by (Richardson & Andersen, 2010) based on (Zagonel, 2002) we can see some close parallels between the operation of group modelling and collaboration in trialogical learning. The circles might represent some of the resources available for collaboration: *current* object reflects the current state of shared knowledge and the *already completed* versions those iterative steps taken by the group to advance their understanding over time. These will contain materialisations of individual internal concepts reorganised as collective knowledge following transformation into a shareable representation. The *client group's mental models* is analogous to the individual and collective unmaterialised knowledge within the group, and the *SD modelling principles* the affordances of the collaborative environment in which they are constructing their shared knowledge objects. The intersections might denote the sociocultural processes the group engages in while working together: *facilitation zone* is that negotiation of worldviews between each other and the knowledge object and the *modelling zone* is the materialisation of those worldviews through the technical constraints of the environment, occurring not only in relation to the knowledge object, but mediated through it and through each other. The *remembering and displaying* intersection denotes the representation of new collective knowledge that is created by the group though this negotiation and materialisation. However, where Richardson divides complex problem solving into a formal, role-based, expert-assisted process focusing on systems, causality and feedback (Richardson & Andersen, 2010), the trialogical model draws on intense engagement with, and socially-related transformation of, both knowledge practices and collective work product over time toward the objective of the activity(Paavola & Hakkarainen, 2021). With this perspective, while the construction of system models is not widely represented in the research on higher education collaboration, trialogical learning, or shared epistemic agency, the potential seems promising.

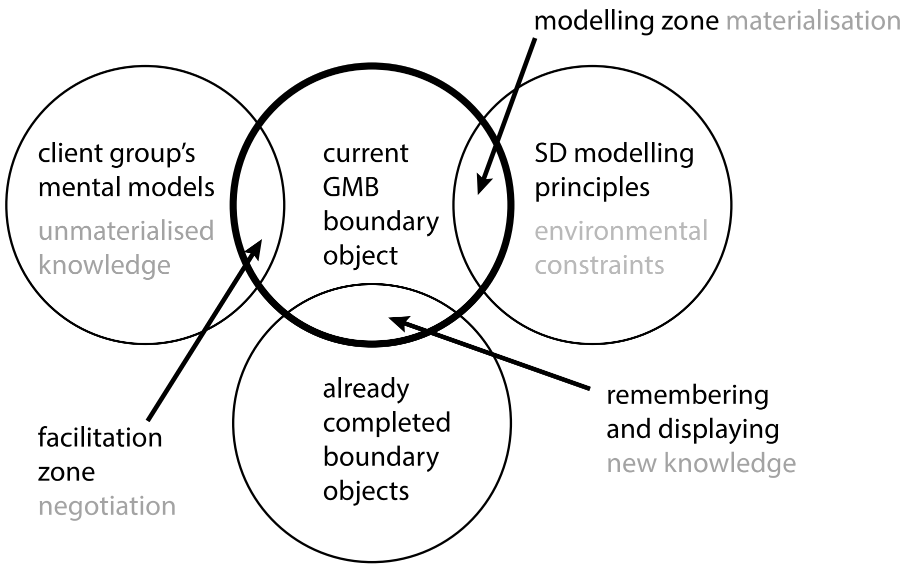

Figure 4: The relationship between collaboration from a knowledge creation perspective and boundary objects in system dynamics group model building adapted from (Richardson & Andersen, 2010) (p. 316, Figure 1).

While the literature around learning with models has primarily focused on individual conceptual change through using them rather than building them (Jonassen et al., 2005), there is increasing recognition of the role that the process of active construction plays at individual and group levels (de Jong et al., 2018; Hmelo-Silver et al., 2015; Jonassen et al., 2005; Linn et al., 2018; Mulder et al., 2016). Constructing models promotes systems (Yoon, 2018), scientific (Hmelo-Silver et al., 2015) and computational (Linn et al., 2018) ways of thinking and knowing, necessary to investigate complex phenomena (Hmelo-Silver et al., 2015), and is now a central practice in professional inquiry (Linn et al., 2018). Using digital tools to represent complex systems at multiple levels is critical to understanding, both as microworlds and boundary objects (Hmelo-Silver et al., 2015). The capacity to develop and use models to visualise, explain, predict and understand phenomena is recognised as a critical skill for K-12 students in the United States and a key Standard in the Science Education Framework (National Research Council, 2012).

There are also recognised limitations. Modelling can increase cognitive load, particularly during initial integration of the diagrammatic and textual information that occurs when learning how to use a modelling tool (Jonassen et al., 2005), with the use of a modelling language a non-trivial task that takes time (de Jong et al., 2018; Linn et al., 2018) and which must be carefully scaffolded (Richter et al., 2012). There are mixed results on usability of different modelling languages (Mulder et al., 2016). Individual modellers can struggle to conceptualise the system as a whole and work better with partial solutions providing an overall structure into which additional variables can be included (Mulder et al., 2016).

Within collaboration for learning, the creation and manipulation of models is understood as knowledge creation activity that goes beyond simple communication and can generate new insights and ideas (Richter et al., 2012). While it's not clear whether the students in the studies by Damşa and Paavola and Hakkarainen used the modelling affordances of the KPE, (Richter et al., 2012) reported two field trials at a European university where the students used its Visual Modelling Language (VML) to solve a complex design problem. While the groups did not make full use of the environmental affordances as they were intended, what is notable is the range of models created. One group created multiple versions of models to trace the evolution of their understanding, another to elaborate and compare different ideas, a third to depict different aspects of their project (Richter et al., 2012). But as well as using models to represent the design space, the groups also used models to organise, monitor and assess their collaborative process (Richter et al., 2012). These findings indicate a potential for group modelling to support not only the epistemic aspects of collaborative inquiry as microworlds and boundary objects, but also social and regulative activity (Richter et al., 2012). These results are indications, although not explicitly reported, of shared epistemic agency.

2.5.4. Summary

These studies show that modelling with others promotes materialisation of individual knowledge to a shared artefactual form, mediated by languages and tools, in an active sociocultural process that develops important skills in thinking about and representing complex systems and which might facilitate the emergence of shared epistemic agency. They demonstrate that computer-supported collaborative modelling is an activity tightly aligned with the trialogical knowledge creation view of learning, which is the foundation for previous studies on shared epistemic agency. There is potential to use group modelling as a pedagogical strategy to facilitate the elicitation and expression of ideas about complex phenomena in a knowledge building setting, fostering the development of important skills in understanding and representing complex systems. However, there has been little research on designing for group model building in computer-supported collaborative learning settings, particularly where sophisticated environments such as the KPE are not available.

2.6. Challenges in collaborative learning design and research

2.6.1. Student concerns about group work

While learners recognise the value of diverse ideas and the new knowledge that is constructed during collaboration, (Almajed, 2015; Cunningham et al., 2016; Stratilas & Yong, 2012; Tucker & Abbasi, 2016), they still express preferences for individual work (Cunningham et al., 2016; Lawrie et al., 2010). Students connect learning gains and positive attitudes with groups that work well together (Lawrie et al., 2010). Consistent concerns are raised by students about how much and in what way each member contributes to the group (Strauß & Rummel, 2021), and the fairness of group assessment (Almajed, 2015; Cunningham et al., 2016; De Grave et al., 2002; Tucker & Abbasi, 2016). Students are also concerned about group leadership (Almajed, 2015; Clear & Kassabova, 2005; Cunningham et al., 2016; De Grave et al., 2002; Hendry et al., 2005; Hendry et al., 2003; Ng, 2008; Tucker & Abbasi, 2016), with many studies highlighting the need for effective facilitation (Almajed, 2015; Cunningham et al., 2016; De Grave et al., 2002; Tucker & Abbasi, 2016). International students in Australia can be particularly reluctant to engage in group discussion (Norton, 2007), particularly if their English language skills are limited (Almajed, 2015; Parkes, 2010). Stratilas and Yong (2012) found that 8.7% of their International student respondents “never” worked with others to prepare assessment tasks (p. 287), and other studies highlight “dread”, “marginalisation”, or finding the situations “problematic” even when all learners are operating in their second language (Hannay & Benestad, 2010, p. 1). International students in Australia who have unsatisfactory group experiences are also less likely to engage in future group activities (Stratilas & Yong, 2012).

2.6.2. Volume and complexity of data collection and analysis

A significant challenge in educational process-related research is the resource-intensiveness that is required to capture the rich depth of data. We have seen the multiple types and high volume of data generated for the group studies even when they have just reported on seven (Damşa et al., 2010), three (Damşa & Andriessen, 2012), fourteen (Damşa, 2014) or thirteen (Damşa & Ludvigsen, 2016) students in between one and three groups. For the first group of seven students, “20 hr of audio recordings of group discussions, 300 e-mails, and 250 intermediate and final group products” (Damşa et al., 2010, p. 156) were the subject of analysis by multiple researchers, a project that would take considerable time and funding. Funding and time are in short supply in the Australian higher education landscape in all areas including and not limited to research, as discussed later in this review, and while any research is ideally globally collaborative and not solely domestic in nature it needs to accommodate local conditions. While many researchers are developing complex approaches to into sensing learner physiological states and movement in the field of multimodal analytics (Schneider et al., 2021), there are also more immediately accessible developments using CSCL environment log file data for both discourse analysis and epistemic network analysis (Oshima & Hoppe, 2021).

2.6.3. Post-hoc results

Another issue is that high quality research studies such as these often provide their findings at some time after the group work has taken place, because the analysis is complex and interpretative. While we don’t know if there are group-specific factors that influence the differences between groups, if there are this does not allow instructor or participant intervention at a time when it could make a difference. This also has an impact on the research paradigms that are available to investigate the phenomenon, because these measurements can not occur until after each longitudinal trajectory is complete, and analysis of each trajectory is essential to capture the unfolding trialogical process involving both the group members and the knowledge object (Damşa, 2014). Studies around the development of tools and approaches to support real-time learner awareness of the socio-cognitive state of a group and its members

(Bodemer et al., 2018; Schnaubert & Bodemer, 2022) have identified unobtrusive data collection from CSCL systems as a key opportunity for research.

2.6.4. Data interoperability

Data interoperability and interpretation can also be a barrier to CSCL research, with institutional systems typically inflexible in their output fields and formats. From the researcher perspective, interaction data may need to be manually entered or multiple steps might be needed to encode it for analysis, even though it is digital, because it is in a proprietary format or licence model, and data from multiple sources may need to be combined. Knowledge object data can be even more nuanced. It is one thing to compare two uploaded versions of a research plan, but how do we understand what the incremental steps were between those versions – the trajectory of the knowledge object (Paavola & Hakkarainen, 2021)? How might we see what Bereiter (2002a) described as the collective norms that determined how the group decided a 'good enough' result? How can we simply compare two knowledge objects when they are in different representational formats or file structures? Methodological challenges such as these have contributed to the lack of penetration of mature CSCL cultures into education systems (Paavola & Hakkarainen, 2021).

2.6.5. Platform affordances

Even before the current reductions in Australian higher education funding and resourcing, universities were increasingly moving to Open Source options for web-based systems, including learning management systems (Dolphin et al., 2017). Open Source software allows free redistribution of source code for modification, meaning substantially-built systems such as the Canvas LMS (Instructure, 2016) can be used without large software licence fees. While that is an advantage, disadvantages include limited features, customisability and support depending on the investment the organisation is prepared to make. Instructors and students often make do with 'out of the box' support materials without contextualisation, and support staff only have access to a more technical version of the same thing. Because this means there might be limited options when it comes to designing for group work, we are seeing increased use of other tools for this purpose, for example, Microsoft Teams and Slack (Menzies & Zarb, 2020), with varying affordances for collaboration and, for students, new processes to learn for each new system. Open source use is also increasing in the workplace, with the Linux operating system supporting 75% of public cloud websites in 2021.

Organisations that don't make open source products still use open source systems, with (GitHub.com, 2021f) reporting that 72% of Fortune 500 companies used their Enterprise platform for collaboration during the 2020-2021 global pandemic.

2.6.6. Summary

The significant potential of CSCL environment data to inform knowledge creation research and pedagogical design has been impeded by the difficulty of scaffolding equitable participation and the potential impact of poor student experiences, the substantial resources and time required for data collection, analysis and reporting, and the technical challenges to accessing, manipulating, and comparing system data about iterative changes to the knowledge object. In addition to the knowledge creation perspective on shared process and artefact production, there are streams of research from other disciplines on how CSCL tools and data can be used effectively to design for cognitive, motivational, social and emotional awareness in groups. However, there has been limited research on how CSCL environments can be designed to support group processes for promoting equitable participation across epistemic and regulative dimensions in a way that facilitates the collection and analysis of both interaction and iterative knowledge object development data, or on how design of these settings might support group processes for the materialisation and production and advancement of complex idea representations.

2.7. GitHub affordances for collaboration in higher education

Designed as a community platform for collaborative software development (GitHub.com, 2021c), GitHub is an online environment in which separate repositories (repos) act like individual websites to which files can be uploaded and shared. However, it is not limited to file sharing; files can be collaboratively edited by multiple people simultaneously with human-readable views of the changes which each editor has made (GitHub.com, 2021d). It offers sophisticated communication and workflow tools for managing contributions and for a transparent view of contribution frequency and quantity (GitHub.com, 2021d). Unlike a traditional website, GitHub pages are formed in a plain-text 'Markdown' language (Cone, 2021; Gruber, 2012), requiring no knowledge of coding, but still displaying properly formatted text, images and code.

An example of a page in GitHub is below at Figure 5, with the following Figure 6 illustrating the Markdown required to generate it.

Use Case 1

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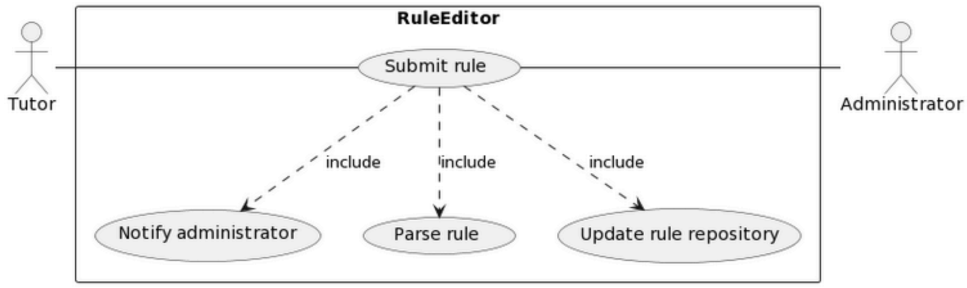



```
@startuml

skinparam packageStyle rectangle

actor Tutor
actor Administrator


rectangle RuleEditor {
    Tutor - (Submit rule)
    (Submit rule) .down.> (Notify administrator) :include
    (Submit rule) - Administrator
    (Submit rule) .down.> (Parse rule) :include
    (Submit rule) .down.> (Update rule repository) :include
}

@enduml
```

Figure 5: Partial screen shot from class GitHub repo illustrating the mix of rich text, diagram and code that can be displayed by rendering plain text Markdown language in GitHub.

````
## Use Case 1

Lorem ipsum dolor sit amet, consetetur sadipscing elitr, sed diam nonumy eirmod tempor invidunt ut labore et dolore magna aliquyam erat, sed diam voluptua. At vero eos et accusam et justo duo dolores et ea rebum. Stet clita kasd gubergren, no sea takimata sanctus est Lorem ipsum dolor sit amet. Lorem ipsum dolor sit amet, consetetur sadipscing elitr, sed diam nonumy eirmod tempor invidunt ut labore et dolore magna aliquyam erat, sed diam voluptua.

![Submit Rule](https://www.plantuml.com/plantuml/img/VL193i8m3Bpx5JwsX_O1750vS4M8vG6c2LNKD8aIHwX2_9sqL6KHgW-MDPuPBm1LOF8SEuq0eLN6aQSE7TKjDVB8lPRePSra6Yq1g6RhyHHJdkgDw9HHWJqD6C1CnaFKSYlKGBe3fXXbM61sZ9TECVf4oCVE5uAbi3TJhZ7RMLRN7kbpH8uhPMeTXVoZB7xMMV3Uamzo0XSSP_xP2UAN83t4sJ0Srh-r20-0IXgHNWbF)


```
@startuml

skinparam packageStyle rectangle

actor Tutor
actor Administrator


rectangle RuleEditor {
    Tutor - (Submit rule)
    (Submit rule) .down.> (Notify administrator) :include
    (Submit rule) - Administrator
    (Submit rule) .down.> (Parse rule) :include
    (Submit rule) .down.> (Update rule repository) :include
}

@enduml
```
````

Figure 6: Partial screen shot from class GitHub repo illustrating the plain text Markdown language to generate the rich text, diagram and code above at Figure 5.

These transparent and persistent views of actions and interactions, individual notifications and on-demand discussions about shared objects of group work were identified as key motivations and benefits for using GitHub as a collaborative platform for learning by (Zagalsky et al., 2015), and are a good fit for the model of trialogical knowledge creation through cross fertilisation of ideas in social interactions mediated by tools and processes to iteratively develop shared knowledge artefacts. As shown at Figure 7, the available tools, views and system functions are substantially similar to those available in the KPE, and can be easily supplemented by project-specific features such as an organisation's standard web conferencing environment.

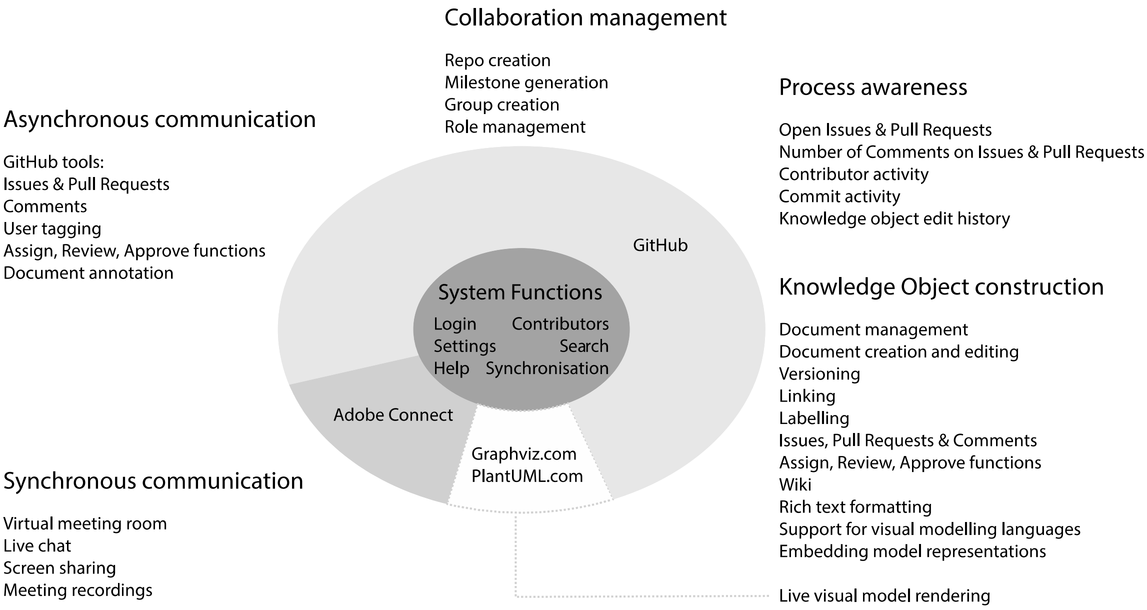


Figure 7: Illustration of the GitHub environment's similarity to the KPE and the different tools supporting the dimensions of mediation it is designed to facilitate.

So far, GitHub has predominantly been used for university collaboration in software engineering courses where its workflow features are considered important for professional expertise as well as for facilitating group work (Haaranen & Lehtinen, 2015; Kertesz, 2015; Tushev et al., 2020; Zagalsky et al., 2015). In their review of the use of GitHub for education, Zagalsky et al. (2015) found instructors typically used it as a substitute LMS to host course material and provide an assessment submission mechanism. Overwhelmingly, available studies identify the challenges of learning how to use the environment as a barrier for both instructors and participants (Fiksel et al., 2019; Kertesz, 2015; Tushev et al., 2020; Zagalsky et al., 2015). However, when universities make decisions on enterprise systems such as LMSs, they tend not to consider either student or staff perceptions, instead addressing barriers to use by providing support material and scaffolding for frequent tasks such as assessment submission. Students who used GitHub also reported academic and professional benefits: that it was a valuable professional skill (Haaranen & Lehtinen, 2015; Kertesz, 2015; Tushev et al., 2020; Zagalsky et al., 2015), that seeing others' work encouraged learning (Kertesz, 2015), participation (Feliciano et al., 2016; Haaranen & Lehtinen, 2015; Zagalsky et al., 2015), collaboration (Feliciano et al., 2016), made multiple solutions visible (Kertesz, 2015), and could lead to fairer grading (Feliciano et al., 2016). There is agreement that more research into effective ways to use GitHub for collaboration in education is necessary (Feliciano et al., 2016; Zagalsky et al., 2015).

Apart from its use in teaching software engineering, recent work citing studies in data analysis, statistics and project management indicates it is not necessarily used in a collaborative context (Fiksel et al., 2019), and outside higher education and software, a recent literature survey across government, academic, civil and private sectors in 2015 identified only seven cases where it has been used for open non-code collaboration, for example, tracking modifications to the Copyright Act of Canada (Longo & Kelley, 2015). However, these relatively low numbers might not be a true indicator of GitHub's probable market trajectory.

There are a range of reasons to consider GitHub a useful platform to conduct exploratory research on at this time. Their launch of a dedicated 'Classroom' product in 2015 (Metz, 2015) has garnered more than a million students, and could be considered a viable component of the open source educational software landscape for this reason alone, but also in conjunction with the increasing focus in education on coding even for very young students. Perhaps more important is its acquisition in 2018 by Microsoft (Microsoft News Center, 2018), who remain the dominant supplier of software (Gartner, 2021f) and of enterprise systems (Gartner, 2018) globally. With Gartner research showing a 44% rise in the workplace use of collaboration tools in since 2019 (Gartner, 2021d), and Microsoft's Teams occupying the top 'Visionary' Leader' position for Unified Communications as a Service Worldwide (which encompasses all core collaboration capabilities excepting what we would see as dedicated idea materialisation technologies) (Gartner, 2021e), we can expect that collaboration technologies supported by Microsoft will become embedded across large organisations that already use their products. It is likely that our students will encounter working with GitHub at some point in their school, university, or working life.

2.7.1. Summary

The GitHub collaborative platform has a novel combination of affordances which have the potential to mitigate several of the key challenges for group work in higher education. While student concerns around equitable participation and grading are likely to be addressed through task and collaborative process design, GitHub's transparent log of user activity encompassing both page changes and communications allows both instructor and learners real-time insights into how the groups are working together in their repo, and can prompt user awareness and early intervention where possible, or differentiated grading where not. While real-time data collection and analysis is not completely seamless, automated capture of user data that happens in the background of normal activity is of significant benefit to both instructors and researchers, usable either alone or in conjunction with other data sources. The plain-text form of both interaction data and modelling code lends itself to machine analysis as well as human interpretation, and to re-use for learner guidance and group self-evaluation.

With resourcing constraints in higher education limiting the opportunities for long-term investment in sophisticated knowledge building environments such as the KPE or Knowledge Forum®. If we are to progress research into effective designs for CSCL, it is necessary to identify alternatives to large-scale institutional environments, with Open Source software use already established across the sector for learning and teaching. The GitHub Open Source collaborative software development environment has affordances which are a good fit for the principles and practices underpinning trialogical learning and collaborative model building, and is a platform widely used in the workplace. However, there is little research on the use of GitHub for CSCL design, and none on its use for collaborative modelling.

2.8. Research gaps

In their 2019 editorial in the *International Journal of Computer-Supported Collaborative Learning*, Sten Ludvigsen and Rolf Steier propose that the most important competence necessary for our students is the capacity to frame complex problems and investigate them by agentically integrating the knowledge distributed across multiple resources in differing representational formats by using digital infrastructures and tools (Ludvigsen & Steier, 2019). This has been the subject of computer-supported collaborative learning research since the 1990s, but despite online learning now being considered mainstream, pedagogies around CSCL are not widely implemented (Stahl, 2015), and there is a need for more insight into the role of both digital infrastructure and digital tools in creating conditions for learning (Ludvigsen & Steier, 2019).

The global pandemic has accelerated the use of fully online environments for both work and education, and teamwork now frequently takes place asynchronously in virtual settings that are designed for interdisciplinary, problem-based knowledge production. University graduates need to leave higher education equipped to work together on projects in which they take collective responsibility for both the negotiated processes and the knowledge advancement of their group. This knowledge extends beyond internal mental states to distributed awareness, material and digital objects, and human and non-human agents and systems. Based in sociocultural theory, knowledge building is an established pedagogical approach shown to facilitate the development of agency and new knowledge creation in a setting underpinned by a networked collaboration environment. However, research on knowledge building is centred in school education (Moss & Beatty, 2006; Zhang et al., 2009), with limited studies on design and implementation in tertiary settings, and often focuses on synchronous collaboration rather than asynchronous knowledge advancement over time. Work on asynchronous collaboration rarely addresses ideas of agency or artefact development.

Within knowledge building research set in higher education, the framework of trialogical learning has established design principles for computer-supported collaborative learning that focus on the role of mediating technology in idea materialisation, group process improvement, and shared knowledge advancement. A series of studies in these settings have demonstrated an association between indicators of agency at individual and group levels and higher-level outcomes. While these studies created a framework for identifying shared epistemic agency though the observation of collaborative processes and iterative knowledge object development, there have been few studies where this construct has been investigated while student groups work in a virtualised environment rather than in groups which meet face-to-face. Research on collaboration that occurs in virtualised environments is often located outside university group work, outside educational collaboration platforms, and in theoretical foundations other than knowledge building.

There is growing interest in the individual and collective benefits of co-constructing models of complex phenomena in education and professional practice, and knowledge creation pedagogies specifically emphasise the way in which digital tools can facilitate the externalisation and structuring of complex, tacit, under-articulated or partial knowledge for advancement by the group. Although our graduates are likely to engage in knowledge work increasingly focused on representations of complex systems, little attention has been paid to the pedagogical design affordances of CSCL environments for materialisation of complex ideas into shareable knowledge objects for higher education group work. Where there is a substantial body of research on collaborative modelling, it is outside higher education, tends to be synchronous, and does not occur in virtualised environments.

There are additional challenges to researching and designing for knowledge creation and epistemic agency in higher education student group settings including the depth and breadth of data requiring collection and analysis and the constraints around resourcing sophisticated sociotechnical environments that support knowledge building principles. Understanding how we can design CSCL environments where this data is accessible and interoperable for use by students, instructors and researchers is an area of significant interest within the Learning Sciences, and new methodological approaches are required to reduce the resources and time required to investigate the processes and products of collaboration.

Professional knowledge environments for virtual, asynchronous collaboration have become mainstream outside education and are likely to be used by our graduates. However, these platforms have not been substantially investigated in relation to the design affordances they provide for university study group work and collaboration research. Studies which have been conducted using GitHub in higher education are located in disciplines where it is used as a professional tool rather than a setting for knowledge building.

This Literature Review has established a need for further exploration of professional knowledge environments as settings for computer-supported collaborative work in higher education based on knowledge building pedagogies in order to identify the design affordances they provide for virtual, asynchronous, project-based group work and research on its outcomes. The following chapter sets out the theoretical framework which has been used to undertake this investigation.

3. Theoretical Framework

3.1. Research aim

The Literature Review has shown that there is increasing demand for research that informs pedagogical design of CSCL settings in higher education which use virtual, asynchronous, project-based teamwork to facilitate engagement in authentic collaborative knowledge creation processes reflecting evolving global work practices. While professional knowledge environments used for workplace collaboration offer a range of affordances for both the process and production of group work, there is little research on how they can be used by university students for collaboration or how the data they contain can contribute to CSCL research.

The first objective of this study is to contribute to CSCL learning design through an exploration of professional knowledge environment affordances and constraints for university student project-based group work.

The second objective of this study is to contribute to CSCL research methodology by investigating how the data from professional learning environments can be collected and analysed for research on collaborative knowledge co-creation.

This study adopts a theoretical foundation of sociocultural theory discussed in the Literature Review, based in Leont'ev (1978); Luria (1971); Vygotsky (1978, 2004), together with pragmatism of Dewey (1997) and the ideas of Piaget (1963), as articulated by Bereiter and Scardamalia (1996), who understand us to be in a constant relationship with our world through lived experience. Knowledge is considered to be distributed (Heylighen, 2014) among human and non-human agents (Clark & Chalmers, 1998; Minsky, 1987; Vygotsky, 1978), systems (Donald, 2004; Fischer, 2006; Hutchins, 1995, 2001), and objects, including cultural practices (Bereiter & Scardamalia, 1996), creative works (Fischer et al., 2018), and other physical, digital and unquantifiable experiences. The sociocultural approach differs from a positivist perspective as it can describe multiple realities in a way that incorporates the authentic experiences of participants (Merriam & Tisdell, 2015).

This theoretical background is operationalised in this study through a pedagogical design based in knowledge building and its extension to trialogical learning (Paavola & Hakkarainen, 2005, 2009). In this framework, learning is understood to occur through complex interrelations of the individual with networks of interacting social and cultural systems and the use of conceptual tools to engage in object-oriented activity to materialise what until then is individual, implicit knowledge into a concrete form for iterative advancement (Paavola & Hakkarainen, 2009).

The following sections discuss how this theoretical base informs the research design.

3.2. Design affordances

The term 'affordance' is generally defined as an environmental feature which holds possibilities for action (Parchoma, 2014). While its origin in behaviourism hold that there is a direct link between visual perception and action (Gibson, 2015), from a sociocultural perspective it is our social relationship with the environment, and how we perceive its relevance to our current purpose which determines how we use environmental features (Parchoma, 2014). In university work, learners do not always take advantages of possibilities that educational technology design offers (Goodyear, 2000) or use the designed affordances in the way that is intended (Stahl, 2009). Instead, they adapt the features of their environment to coordinate their understanding (Stahl, 2009).

Affordances of particular pedagogical approaches or technological environments for collaborative learning are intended to support a comprehensive set of cognitive and social engagements. Jeong and Hmelo-Silver (2016) have identified seven core affordances in CSCL to support key processes in successful collaboration: opportunities to engage in a joint task, communicate, share resources, engage in productive collaborative processes, engage in co-construction, monitor and regulate collaborative learning, and find and build groups and communities. Effective CSCL requires technologies that support these core processes (Jeong & Hartley, 2018). Design principles for knowledge building also incorporate aims of creativity and innovation, research and problem solving, plus broader social aims around social participation and responsibility (Scardamalia et al., 2012).

Within knowledge building, and specifically trialogical learning, the environment is designed at a high level to mediate epistemic, pragmatic, social and reflective activities (Paavola et al., 2012), with affordances for collaboration management, process awareness, and knowledge object construction (Metropolia University of Applied Sciences, 2021; Paavola et al., 2011). While some of these are mainstream in both education and the workplace, for example, document management, the visual modelling editor is a specific affordance for mobilising tacit knowledge in a shareable form (Lakkala et al., 2010; Paavola et al., 2011).

Affordances can be simple, like access to authoritative sources (Yeo & Tan, 2010), social, for example, visibility of other group members also online (Kreijns et al., 2013), and scaffolds, such as prompts or frameworks that can be used to synthesise ideas (Scardamalia et al., 2012). Affordances are often provided in CSCL as tools, for example, an editing space supporting multiple representational forms which can be used as social and cognitive affordances to construct emerging knowledge (Suthers & Hundhausen, 2003).

In this study, affordances are defined as features of the designed task, collaborative environment, and instructional context, although it is understood that their appropriation by learners will be dynamic and contextual (Parchoma, 2014).

3.3. Professional knowledge environments

There are a range of platforms used for collaboration in professional workplaces, with no specific definition of what comprises a 'knowledge environment'. Some examples are GitHub (Zagalsky et al., 2015), Microsoft Teams, Slack (Menzies & Zarb, 2020), and Trello (Han et al., 2021). Generally, professional collaboration tools provide communication tools (Menzies & Zarb, 2020) within a conversational online workspace and are used to organise, coordinate and execute project-related activities (Gartner, 2021g; Han et al., 2021). In contrast, typical LMSs used in universities provide systems for delivering course content, facilitating assignment submissions and tracking grades, and are used primarily for administrative purposes (Zagalsky et al., 2015). Barriers to the implementation of professional knowledge environments in higher education include institutional alignment with specific platforms and products, administrative complexity and resourcing.

Learning Management Systems provide variable affordances for collaboration depending on the product and institution, and these might include a persistent threaded discussion or chat to which documents can be appended. They do not often provide a shared authoring environment for knowledge materialisation, log of iterative modifications to a shared knowledge object, or affordances for groups to manage their collaboration processes. Professional knowledge environments provide a constantly-evolving range of features with significant overlap, for example, both Microsoft Teams and Slack have team chat and integration with email and productivity applications, but Teams has stronger support for meeting organisation and videoconferencing and Slack has more support for automation (Duò, 2022). While GitHub is mostly associated with software development teams, its multiple affordances for co-constructing parallel graphic and textual representations in a way in which all contributions are tracked makes GitHub a promising authentic and low-cost knowledge environment for project-based modelling tasks designed to facilitate technology-enabled object-oriented collaboration.

3.4. Collaborative task

There is a central emphasis in the Learning Sciences on constructing authentic tasks and situations for learning design and research (Goldman & Brand-Gruwel, 2018). Pedagogical tasks that use problem-solving are frequently used in collaborative learning design (Hmelo-Silver et al., 2013; Hmelo-Silver et al., 2018). When learners approach an ill-structured problem, they must elicit prior knowledge in order to analyse and frame solutions through self-directed research, and frame it as useful in other settings with similar features, which supports the development of conceptual understanding as well as self-regulation in addition to the problem-solving skills themselves (Hmelo-Silver et al., 2018). Problems without clear answers and where the expertise of the whole group is required to complete the task encourage both participation and the valuing of others' perspectives (Webb, 2013). The task problem should be complex enough that learners have to go beyond memorised information to the Zone of Proximal Development (Fischer et al., 2018). While low levels of guidance can increase cognitive load (Kirschner et al., 2006), this can be addressed by design decisions that facilitate self-regulation, secure a prior knowledge baseline distributed heterogeneously among team members, leverage prior group and task experience, ensure a magically appropriate group size, and construct a complex task that requires social interdependence with a technological foundation offering affordances for the group's collaborative and problem-solving processes (Janssen & Kirschner, 2020).

Problem-based, inquiry-based and project-based learning are all variations of collaborative learning (Sawyer, 2013). Inquiry-based learning is widely recognised and advocated in higher education (Aditomo et al., 2013) and generally involves a question that students investigate with instructor guidance (Aditomo et al., 2013). The progressive inquiry variation shares a theoretical foundation with knowledge building and trialogical learning, and their design for idea materialisation and iterative knowledge advancement through technology-mediated collaboration (Muukkonen et al., 2005). However, it has a specific dimension where the emphasis is on decomposing questions and creating hypotheses for the phenomenon being investigated (Muukkonen et al., 2005).

As a form of inquiry learning, project-based learning has a variety of interpretations (Bereiter, 2002a, 2002b), but it is distinguished by a specified end-product which requires iterative problem-solving steps and the application of knowledge to construct it (Aditomo et al., 2013), so it has strong alignment with the knowledge creation paradigm (Damşa & Nerland, 2016). In knowledge project-based learning is specifically centred on student-designed inquiry into authentic questions leading to new knowledge creation in the form of a conceptual artefact (Bereiter, 2002a). The students and instructor co-construct the inquiry rather than relying on pre-defined tasks (Chan & Van Aalst, 2018; Tan et al., 2021), with the teacher's role to highlight the learners' epistemic needs, working as a fellow knowledge builder (Chan & Van Aalst, 2018).

Learning design for group work using problem-based pedagogies supports learners to iteratively identify gaps in their knowledge and work collaboratively to address them (Dennen & Hoadley, 2013), developing metacognition, reflection and shared epistemic agency (Chan, 2013; Damşa et al., 2010). Knowledge creation approaches that centre student negotiation of ideas and self-regulation (Chan & Van Aalst, 2018) facilitate epistemic agency (Vogel & Weinberger, 2018).

The task design for this study draws from the knowledge building perspective of inquiry co-construction, but modifies the instructor role to be feasible in a part-time blended higher education context.

3.5. Types of agency

Agency is both a learning mechanism and an outcome relevant to the aim of equipping learners to productively engage in virtual, asynchronous collaborative work. Agency can emerge individually or collectively through collaboration (Cress & Kimmerle, 2018), however developing collective agency remains challenging (Tan et al., 2021). The relationship between different levels of agency requires further research (Cress & Kimmerle, 2018; Damşa, 2014).

Agency is conceptualised from different theoretical perspectives as a combination of cognitive, social and emotional aspects (Ludvigsen & Steier, 2019), temporally situated with view of past, present and future (Emirbayer & Mische, 1998), characterised by self-regulation and self-reflection (Bandura, 2001), existing as a resource for responding to pressing social needs (Sannino, 2022). In the relational-pragmatic view, agency contains *iterational*, *projective* and *practical-evaluative* dimensions (Emirbayer & Mische, 1998). The *iterational* dimension relates to the ability to recall and apply knowledge developed through past activities and looks back to Aristotle's *hexis* as a disposition in action (Aristotle, ca. 350 B.C.E./1999, bekker line 1098b), and Dewey's idea of will (Dewey, 2002); the *projective* relates to future orientation and the creation of possibilities for action, recalling Dewey's "instrumentality for dealing with the future" (Dewey, 1997, p. 8); and the *practical-evaluative* to practical responses to present contingency, like Aristotelian *phroenesis*, and Dewey's pragmatism (Emirbayer & Mische, 1998). Emirbayer and Mische (1998) built on Alexander's (Alexander, 1988) view of agency as an interpretative process of contextually embedded actors, proposing that agency is inextricably linked to the "changing temporal action of situated actors" (Emirbayer & Mische, 1998, p. 967). This relies of the concept of time existing as emergent events requiring a continual refocusing of past and future, and of human consciousness as constituted through sociality, situated contextually both relationally and temporally (Alexander, 1988), which aligns with sociocultural theory. The concept of *bi-directional constructive* agency is specifically sociocultural, with human actions in a co-constructing relationship with the environment mediated by symbolising activities (Damşa, 2014).

In learning, *productive* agency draws on Marxist theory to emphasise the productional nature of contributing to the world (Schwartz & Lin, 2001). From this perspective, individual agency is a necessary condition for collaboration because of the efforts made to achieve shared meaning and because when people can exert their agency through productive behaviour it increases their motivation (Schwartz & Lin, 2001). Pickering (1995) conceptualised the *material* agency of non-human agents, as well as *disciplinary* agency which relates to the discretion with which specific systems such as algebra might be applied in *conceptual* practice. *Epistemic* agency contains the temporal, relational and situated perspectives of (Emirbayer & Mische, 1998) as well as the productional perspective of (Schwartz & Lin, 2001) with a specific emphasis on how this production leads to knowledge advancement, and requires a task with affordances for agentic action (Gresalfi et al., 2009). While there are social dimensions to all these framings of agency, they still operate at an individual level (Damşa, 2014).

Within knowledge building, the collaborative nature of work requires attention to the intersection between individual and collective agency (Damşa, 2014). This additional conceptualisation of *epistemic* agency relates to the contribution by individuals to collective knowledge and its advancement through refinement (Hakkarainen et al., 2004; Palonen &

Hakkarainen, 2000; van Aalst & Chan, 2007), with the group the unit of analysis (Damşa, 2014). Agency in these studies was understood as a shared phenomenon associated with interactions, changes to knowledge objects and group organisation processes (Damşa, 2014). *Shared epistemic agency* can be indicated by a combination of these actions over time (Damşa, 2014).

In order to understand how agency might emerge in the context of this study, it is necessary to establish how it can be identified in university student knowledge building, but few studies investigate this phenomenon.

(Oshima et al., 2013)'s multivocal analysis of multilayered agency approached existing discourse data through Social Network Analysis and dialogical analysis finding them complementary approaches for identifying pivotal points in knowledge advancement and individual contribution patterns, with the following study using the same methods with a live class of eight undergraduate engineering students (Oshima et al., 2015). Pivotal points were identified initially by a change in group vocabulary associated with a sequence of exchanges representing alleviation of lack of knowledge (Oshima et al., 2013; Oshima et al., 2015). While these learners were not using a CSCL environment, this indicates the potential for student interaction data to be used in knowledge building research on epistemic agency.

Like Oshima et al. (2015), Damşa (2014); Damşa and Andriessen (2012); Damşa and Ludvigsen (2016) studies of shared epistemic agency were situated in knowledge creation, and specifically trialogical learning. Their substantial contribution to research on shared epistemic agency is discussed in the Literature Review. Damşa et al. (2010) framework for identifying indicators of shared epistemic agency structures agentic actions into *epistemic* (knowledge-related activities such as restructuring ideas) and *regulative* (process-related actions like monitoring task progress) dimensions (Damşa et al., 2010). Group activity across both dimensions is associated with new knowledge creation (Damşa, 2014; Damşa & Andriessen, 2012; Damşa et al., 2010; Damşa & Ludvigsen, 2016). Damşa (2014) had similarities to the Oshima et al. (2013); Oshima et al. (2015) work in that it also looked at how individual actions were connected to concrete advancement of the knowledge object, still in the context of shared epistemic agency.

While in Damşa's studies teams met face-to-face and synchronously, they used online collaboration platforms for group work on ill-structured project-based authentic design tasks designed from the trialogical perspective, so the setting and task is similar to that of our student participant cohort, and the type of interaction and artefact production data used in these studies on shared epistemic agency is similar to that which is produced in the course of our project. The framework offers a classification system encompassing the foundational concepts of Emirbayer and Mische (1998) and Schwartz and Lin (2001) which can be applied to any data format and analysed at multiple levels, meaning a categorised dataset could be accessible for other types of analysis, including machine analysis such as network analysis (Oshima et al., 2013; Oshima et al., 2015; Shaffer, 2017; Shaffer et al., 2009; Shaffer & Ruis, 2017), studies of multi-level interaction over time (Malmberg et al., 2017; Malmberg et al., 2022; Suthers, 2015), and complex emerging analytical frames like collaboration (Martinez-Maldonado et al., 2021) or knowledge building (Tan et al., 2021) analytics. Understanding more about how groups manifest agency is an area of research interest, as is the connection between individual and collective agency (Tan et al., 2021). Using the indicators of shared epistemic agency developed by (Damşa et al., 2010) to understand more about collaboration will contribute to existing and emerging research fields in CSCL.

3.6. Research in CSCL

The Learning Sciences and CSCL are multi-disciplinary fields (Hmelo-Silver & Jeong, 2021a) with a range of research methodologies reflecting the diversity of disciplines and theoretical perspectives informing them (Cress, Oshima, et al., 2021; Fischer et al., 2018). Research aims are to investigate how meaning is constructed in order to design environments in which that can take place (Cress, Oshima, et al., 2021; Fischer et al., 2018). In research on collaborative learning, learner interactions are important because some phenomena are only apparent through this observation (Vogel & Weinberger, 2018), and because it allows the testing of hypotheses about the process of collaborative learning (Vogel & Weinberger, 2018).

A firm theoretical base is required to investigate collaboration (Vogel & Weinberger, 2018), and theoretical approaches differ depending on the scope of the study and the phenomenon under investigation (Jeong & Hartley, 2018). Research designs may be descriptive, experimental, or design-based (Jeong & Hartley, 2018). Diverse data sources are used, including audio, video, messages, log data and digital artefacts (Jeong & Hartley, 2018), and multiple data sources are often used to triangulate findings (Jeong et al., 2014). Any methodology should be appropriate to multi-level analysis (Cress & Kimmerle, 2018). Future research should explore both the interactions surrounding digital artefact production and the details of its development process (Trausan-Matu & Slotta, 2021).

Where intended to be sensitive to learning situations, the most appropriate approach is considered to be to use a balance of qualitative and quantitative methods (Hoadley, 2018). Around three quarters of CSCL studies use coding prior to quantitative analysis (Jeong & Hartley, 2018), and around half rely on qualitative analysis alone (Jeong & Hartley, 2018). Quantitative methods can improve validity, and qualitative methods can identify specific processes or activities which impact learning (Vogel & Weinberger, 2018). While there have been calls for more randomised experiments, the variability of settings is unlikely to generate results with true experimental validity (Jeong et al., 2014). Although there is some methodological tension between qualitative and quantitative approaches (Stahl, 2017) progress toward a combination of these traditions is desirable (Jeong et al., 2014). There is a need for direct replication of important existing studies, particularly with quasi-experimental research (Janssen & Kollar, 2021).

Within the sociocultural framework, ethnomethodological methods (Koschmann & Schwarz, 2021) and conversation analysis are frequently used to examine interactions (Cress & Kimmerle, 2018; Lee & Tan, 2017a; Oshima & Hoppe, 2021; Trausan-Matu & Slotta, 2021; Uttamchandani & Lester, 2021). There is increasing research interest in improving automated analysis of interaction through text classification technologies (Rosé et al., 2008), particularly for emerging approaches such as social and epistemic network analysis (Cress & Kimmerle, 2018; Trausan-Matu & Slotta, 2021) and Quantitative Ethnography (Shaffer, 2017). There is significant crossover between learning analytics and CSCL design and research in this area (Lee & Tan, 2017a; Oshima & Hoppe, 2021), and a need for tighter alignment with a strong theory base (Rosé, 2018). While new discourse analytic perspectives are growing in CSCL, conversation analysis and interaction analysis remain the 'mainstays' of research for studying learning and collaboration (Uttamchandani & Lester, 2021).

While it has been argued that the sociocultural and constructivist frameworks have different analytical focus, with the former interested in the contextual features of interaction (Cress & Kimmerle, 2018) and the latter in active engagement (Jeong & Hartley, 2018), the trialogical framework could be considered to integrate these perspectives with its dual emphasis on processes and knowledge object advancement. The studies by (Damşa, 2014; Damşa & Andriessen, 2012; Damşa et al., 2010; Damşa & Ludvigsen, 2016) offer a theoretically-robust framework for analysis of interactions and knowledge objects at multiple levels in a way which incorporates both qualitative and quantitative data and has the potential to contribute not only to studies of how learners work together, but also to how the data from this work in professional knowledge environments might be used by the complex systems of human- and non-human agents facilitating project-based group work in higher education.

4. Research Methodology

The previous chapter defined the theoretical framework resulting from the Literature Review that underpins this research. It considered how it informs the design decisions that will be used to operationalise the inquiry into the kind of agency that emerges when university students work on project-based tasks using professional knowledge environments at individual and collective levels, and how the data from these environments might be used for research on knowledge co-creation. This chapter sets out the research methodology in detail.

Section 4.1 discusses the case study design. Section 4.2 describes the research setting and participants, and the steps taken to ensure compliance with Human Ethics protocols. Section 4.3 discusses the design of the collaborative tasks the project group engaged in. Section 4.4 details the design of the collaborative environment. Section 4.5 sets out the data collection procedures. Section 4.6 provides an overview of the data analysis procedures. Section 4.7 describes in more detail the procedure for the first level thematic analysis and classification of individual actions and interactions into categories of epistemic and regulative actions, and the process by which the findings are triangulated against secondary data sources. Section 4.8 describes in detail the procedure for the second level trajectory analysis of those sequences of productive joint action resulting in knowledge object advancement.

4.1. Case study design

The case study research approach for this study is based in the Learning Sciences paradigm of qualitative observation and systematic design efforts (Fischer et al., 2018) and is aligned with traditional educational research in its goals of discovery, insight and understanding through qualitative research (Merriam & Tisdell, 2015). Case studies are used across the social sciences, and are variously described as approaches, designs, and strategies of inquiry (Merriam & Tisdell, 2015). Methodologies such as interaction analysis and conversation analysis are traditionally used in case studies as they allow intensive examination in detail (Bryman, 2012) where the context is localized and the findings not necessarily generalisable (Danish & Gresalfi, 2018). CSCL studies frequently use a blend of these qualitative and quantitative approaches (Hoadley, 2018; Jeong & Hartley, 2018; Vogel & Weinberger, 2018), and there is a need to gain access to more quantitative data in order to guide design-based research (Stahl, 2017).

The case study method is also relevant for this research as similar studies have generally used case methods (Damşa, 2014; Damşa et al., 2010; Damşa & Ludvigsen, 2016) or field trials which use cases as descriptive examples (Richter et al., 2012). Case methods allow an "in-depth description and analysis of a bounded system" (Merriam & Tisdell, 2015, p. 40), particularly where the variables of the phenomenon of inquiry can not be separated from their context (Merriam & Tisdell, 2015). The bounded system and unit of analysis for the single case is the activities and products of three participant groups during the seven-week study period, with each group an embedded object of interest in its own right as shown at Figure 8.

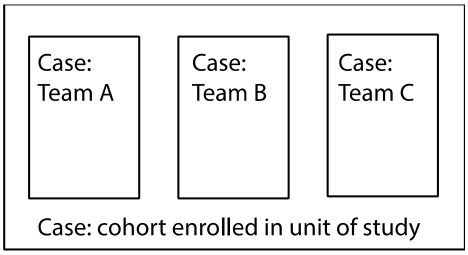


Figure 8: Illustration of the embedded case study design used for this research.

(Yin, 2003) would describe this type of case study as having elements of *descriptive* and *exploratory* types more than *explanatory,* as it looks at what might be observed about the characteristics of collaboration and indications of epistemic agency in the student groups, and tests whether the research procedure might be useful for future studies, but does not establish a cause for the phenomenon under investigation.

4.2. Research design

4.2.1. Setting and participants

The research was situated at a public Australian university in late 2019. The participants (*N*=16, 13 females, 3 males) were enrolled students in a postgraduate Learning Sciences unit that engages learners in instructional and other types of design and modelling. Two students withdrew from the unit during the study. The study uses a convenience sampling method, with a sample consistent in size with Damşa (2014); Damşa and Ludvigsen (2016), in composition with Damşa and Ludvigsen (2016)'s Teaching Education Professional Environments cohort, in domain of instruction with Damşa et al. (2010); Damşa and Ludvigsen (2016), and typical for a unit of its kind. While convenience sampling has a risk of bias as the participants may not adequately represent the target population (Yin, 2015), it is frequently used in social research, and may be appropriate where there is a need for preliminary analysis (Bryman, 2012). While all non-probability sampling methods have the risk of volunteer bias, it is an acceptable method for an exploratory study where broad generalisation is not the objective (Bryman, 2012).

4.2.2. Ethics

This project was conducted under protocol 2019/049 (Appendix A) after obtaining permission from the university's Human Ethics office. Approval was granted after study proposal demonstrated that this is low-risk research that does not involve vulnerable populations or sensitive personal information. The population is not considered vulnerable as it comprises postgraduate, generally adult, students who are accustomed to the communication channels usually used by the University, such as the Canvas LMS then in use, and whose levels of language competence are appropriate to postgraduate tertiary study.

Participants were recruited by being verbally advised about the study and its purpose in class and invited to take part. They were provided with both a Participant Information Statement (Appendix B) and Participant Consent Form (Appendix C) which explained the study and their options for consent, as well as the data that would be collected and how it would be used. Participation in the study was voluntary, and neither instructor nor researcher knew which students were participating until all assessable work was returned and administrative processes completed. The group project task was cross-graded by another Learning Sciences academic to ensure even unintentional marking bias was avoided. The researcher's role in relation to the participants was to provide scaffolding around the task and environment, and just-in-time technical support for both the collaborative platform and the Unified Modelling Language (UML) (Object Management Group®, 1997).

All data collected in this study and derivative documentation has been managed in accordance with the Research Data Management Plan (Appendix D). In the data collection process, data was downloaded from the collaborative environment and uploaded to the University's Research Data Store for secure and redundant storage (The University of Sydney Chief Information Officer, 2018) [university intranet login required]. Access and security has been managed by the researcher in accordance with university policies and procedures (The University of Sydney, 2018a, 2018b) with fine control available through the University's Research Data Management systems (The University of Sydney Director, 2018).

4.3. Collaborative task

The unit of study in which the participants were enrolled focuses on design considerations for influencing the character and outcomes of learning (The University of Sydney, 2020). It offers a model of the architecture of learning situations, and suggests ways of identifying which tools and techniques are the most appropriate for the specific design challenge (The University of Sydney, 2020). The learning outcomes are (1) demonstrate understanding of contemporary educational design theories and approaches, (2) make informed decisions about using educational design methods, (3) apply conceptual knowledge to real-world design examples, (4) apply knowledge about design methods to create new instructional designs[7] (The University of Sydney, 2020).

To support these outcomes a collaborative environment and project-based tasks were designed using knowledge building (Scardamalia et al., 2012) and trialogical learning principles (Paavola & Hakkarainen, 2005). The focus was on advancing the state of knowledge (Bereiter, 2002a; Scardamalia et al., 2012) through technology-mediated shared document co-construction (Paavola & Hakkarainen, 2005, 2014; Reimann et al., 2011; Scardamalia & Bereiter, 2021), student-led collaborative processes (Paavola & Hakkarainen, 2005, 2014; Reimann et al., 2012; Reimann et al., 2013), the materialisation of knowledge (Paavola & Hakkarainen, 2009) and development of complex systems thinking (Hmelo-Silver et al., 2015; Linn et al., 2018; Yoon, 2018) through group model building, and the public restructuring of knowledge through productional activity (Scardamalia et al., 2012; Yoon, 2018). Students were also assessed on an individual topic presentation, essay and reflection task, which are not considered in this research.

4.3.1. Collaborative Task 1

As preparation for the assessable group project, the students first collaborated in triples in an ungraded research task. Groups were formed randomly by spinning a wheel containing student names (Wheel Decide, 2021). The task was to search for websites relevant to learning designer professional development and to conduct an analysis on an interesting site using design principles and patterns, using a template in the university's Enterprise GitHub system to construct a shared and shareable knowledge object with a relationship to the assessable task

[7] While this link is for the 2020 EDPC5022 Learning Outcomes, they are the same as 2019. However, the assessment in 2019 was different, and is set out above.

design. The task specification contained examples of suitable websites, texts on design, a suggested timeline for conducting work over the three weeks, a link to the templates in GitHub, and scaffolding for using GitHub workflows.

As well as providing an opportunity to work together without immediate concern about grading, this task was designed to familiarise the cohort with the unit content, the GitHub professional knowledge environment (GitHub.com, 2021b) and the Markdown language (Cone, 2021), all important to the subsequent group task. The assessment processes are deliberately formative, with each task contributing to the subsequent task, facilitating academic integrity, and a learning trajectory transparent to both the learner and the instructor.

4.3.2. Collaborative Task 2

At the beginning of the project that is the object of this study, participants formed themselves into three groups of six, with two groups comprising two original triples each, with the third group combining the remaining members of triples where some members had not continued with the course. The instructor set the group size at six to allow sufficient diversity of viewpoints while at the same time reducing the socialisation overload leading to inhibited decision-making that might occur with a larger group (Looi & Wong 2018). The group project task specification is at Figure 9.

Your task is to design a 'future' learning design environment (2025). You will be in the role of meta-designers. Your stakeholders are (a) a manager sponsoring the development of a design support platform and (b) a team of developers of that platform.

The main questions that need to be considered are:

- What kind of learning environments will designers have to create in 5 years?
  - Pedagogy, technology, content?
  - Data use and analytics?
- What kind of methods and technologies (for designing and collaborating) will/should have learning designers available in support of their work in 5 years time? What kind of constraints will they work under?

The group project requires (a) analysis of the state of the art and (b) the development of designs for future design environments. The group project is divided into three phases:

1. The **state of the art analysis** will mainly be done in the weeks before the group project starts; it will be done in dyads.
2. **Envisioning the future** involves brainstorming ideas for two future (think 2025) scenarios, an "achievable" and an "ideal" one.
3. **Designing the future** involves modeling key parts of one or both of the future scenarios.

See assignment philosophy for options on how to go about this assignment.

Main grading criteria:

1. Extent and depth of the research into and analysis of existing solutions;
2. Suitability of the design decisions and quality of the design rationale
3. Soundness of the group design and decision making process; quality of its documentation

Figure 9: Task specification for Collaboration Task 2, the assessable group project.

The project took place over seven weeks (Week 6 to Week 13 of the teaching session), with each group working to co-construct a meta-design using the GitHub environment and UML. The design had three elements each of which had a template in the repo: *Use-cases.md, Components.md* and *Interactions.md.* These templates included structured rich text, example model diagrams, and the UML code used to generate each example. The design purpose of shared model construction from a trialogical perspective is set out in the Literature Review at Section 2.7. Using a modelling language rather than a simple graphics editor to do this embeds the conceptual framework of systems thinking, showing causal relationships between the parts, their direction and impact, over time (Morecroft, 2007). This is a fundamental conceptual framework needed not only by those who design learning situations, but also for the learners themselves, who will emerge in to a world overwhelmed by complexity (Senge, 1992), collaboratively solving problems characterised by "connectedness, complexity, conflict, multiple perspectives and stakeholdings" (Ison, 2008, p. 146). Learning to engage in these kinds of collaborative tasks need a high level of cognitive sophistication (Paavola & Hakkarainen, 2005) and a designed environment that mirrors the situations in which learners are likely to apply what we are teaching them (Goodyear & Zenios, 2007). However, the Literature Review shows at Section 2.5.3 that learning a modelling language is not a trivial task.

Unified Modeling Language is notation used to describe a model, often a software model, in a way that includes their structure and design including their connections to other systems and agents (Object Management Group®, 1997). It is particularly suited as an entry-level modelling language for several reasons. First, it is plain text-based, simple and intuitive, written in natural language that logically describes the actions taking place in the system being modelled, without the need for specialist terminology. This reduces the barrier between what the student wants to express of their mental model, and what can be expressed in the model notation, and mitigates the difficulty of using modelling languages sometimes experienced by novices (de Jong et al., 2018; Jonassen et al., 2005; Linn et al., 2018; Richter et al., 2012). For example, the code sequence on the left of the illustration below at Figure 10 is sufficient to generate the model on the right.

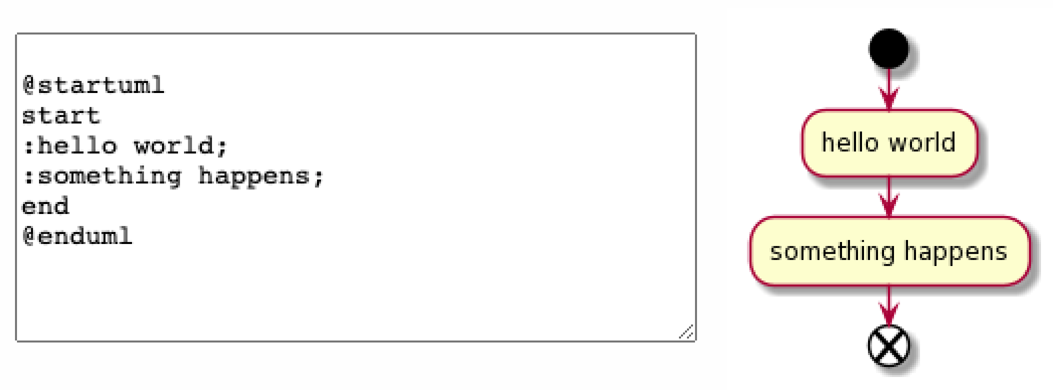


Figure 10: Example of UML code to generate a simple model. Model generated using (PlantUML.com, 2021).

Second, the text format has significant advantages for editing, reporting and providing system feedback on model validity. If, for example, the designer wanted to *add something* in the model before *something happens* and the model was created in a drawing application, the drawing would require substantial edits to modify it. Using UML, adding a line of text is enough to regenerate the model, as shown in Figure 11.

Figure 11: Example of editing UML code to regenerate a model. Model generated using (PlantUML.com, 2021).

Should the designer make an error of syntax that invalidates the model, the system will let the know where to look for the mistake. In the illustration at Figure 12, where a semicolon is purposefully omitted, line 5 is highlighted and the code does not proceed past its end, indicating that this is the point where the error occurs.

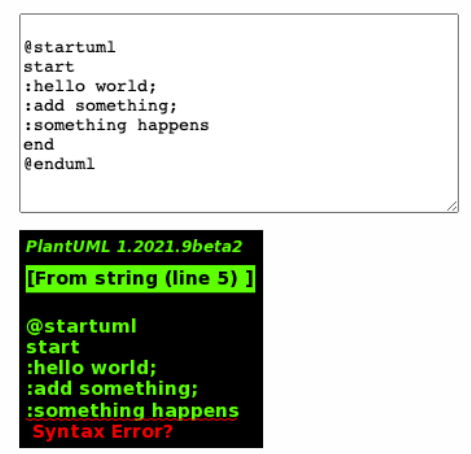


Figure 12: Example of syntax error alert in UML code. Alert generated using (PlantUML.com, 2021).

Third, with a real-time graphical editor such as PlantUML (PlantUML.com, 2021) or Graphviz (Ellson & Gansner, 2018), the narrative and visual views can be viewed in parallel as illustrated at Figure 13, with the results of manipulation being immediately available to the user. These features allow the designer to vary the design parameters of the model and observe whether the effect matches their prediction, engaging in the three essential processes for active learning: selecting, organising and integrating material with existing knowledge (Mayer, 2014). While in general Mayer's theory of multimedia learning focuses on instructional texts and narration, this modelling method accords with a number of its other principles: there are few extraneous details, the system feedback highlights what to pay attention to (Mayer & Fiorella, 2014), the words and pictures are semantically related to each other (*coherent*) and presented adjacent to each other in space, and simultaneously in time (*contiguous*) (Schnotz, 2014).

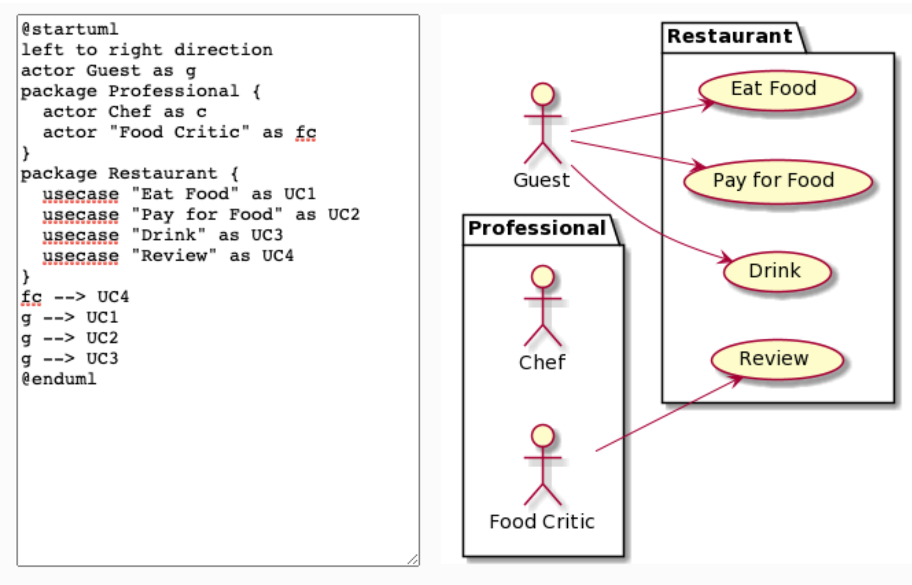


Figure 13: Example of the multiple representational format possible while writing UML in a graphical editor. Model generated using (PlantUML.com, 2021).

Each class included around 20 minutes of skill building using an online UML editing environment (PlantUML.com, 2021), with students following worked examples which were demonstrated by the instructor. Outside class, small ungraded weekly milestone tasks using PlantUML were set for groups with the explicit aim of creating increasingly sophisticated models for both collaborative process and domain understanding. An overview of these tasks is at Table 1. Documents that were used for knowledge object analysis are in roman type and those used for triangulation are in italic type. Groups were also encouraged to record insights into their process at another document, *Insights.md.* While it was not originally intended to analyse the *README* file as a knowledge object, as one team used it as an epistemic rather than process artefact it is included in the set of 'assessable knowledge objects'.

Table 1: Instructor milestones during the collaboration task and the associated knowledge object.

Week	Instructor task	Target model or document
6	Develop group process	*Processes.md*
6	Update links in README.md	README.md
6	Generate use cases for automated course design functionality (Week 7)	Use-cases.md
7	Add component and interaction diagrams for automated course production functionality (Week 8)	Components.md Interactions.md
8	Update README.md to reflect state of play by Friday, 19. April COB	README.md
9	Develop ideas and use cases for including Design Critique functionality (Week 9)	Interactions.md Use-cases.md
9	Conduct a design critique for your most advanced model so far.	Interactions.md
10	Make your ideas for including design critique in an LDE concrete by specific use case and interaction sequence diagrams (Week 10)	Interactions.md Use-cases.md
10	Review your work process and update contributing.md as needed	*Contributing.md* *Processes.md*
11	Optional: Extend the LDE by designing for 'smart' handling of data coming from learners (learning analytics and feedback)	Components.md Interactions.md Use-cases.md
12	In class knowledge exchange: share on screen and talk about a model your team has constructed	[self-selection]

4.4. Online environment

The designed environment comprised a combination of platforms and tools designed to be easily adaptable by learners for their epistemic, regulative and social collaboration. The GitHub platform has similar affordances to the Knowledge Practices Environment developed for trialogical learning, with views, tools and navigational features broadly distributed between process, community, and artefact creation and modification although not neatly divisible into specific areas or views, as illustrated in the Literature Review at Section 2.8.2. Table 2 sets out the components in more detail; with features which were added to the environment when a need was identified in italic type.

Table 2: Designed environment features in detail.

Type	Purpose
Collaborative platform: Adobe Connect meeting room	Support for synchronous & asynchronous meeting activities with shared meeting tools such as whiteboard, notes, screen sharing & online meeting recording.
Collaborative platform: GitHub collaboration environment	Support for synchronous & asynchronous activities with project-oriented tools such as milestones, Issues and workflow systems; plus documentation and participation logging. Model representation supported in Markdown (text) and linked Graphviz (diagram) forms.
Conceptual scaffolding	Examples, instructions, and webtools for using PlantUML, Graphviz and Markdown. UML models in document templates for each model type.
Modelling tools and notation	PlantUML, Graphviz and Markdown languages and tools, completed and partially-completed models of multiple types.
Group regulation tools	Templates for role-based workflow such as facilitation scheduling, meeting notes & reports provided for students to adapt to their context.
Group social and epistemic tools	Activity templates describing typical collaboration/meeting activities such as ideation, elaboration, refinement and evaluation, and how to instantiate them on GitHub and Adobe Connect provided.
Group design tools	Workflows for iterative design and decision making and how to instantiate them on GitHub and Adobe Connect.
Group tool scaffolding	Help information, FAQs and (video) tutorials at beginner, intermediate and advanced levels for all the tools and platforms used in the unit.
Conceptual scaffolding	*Step-by-step instructions, disambiguation and elaboration added to the class GitHub repo wiki.*
Just-in-time individual assistance	*Personal and individual assistance provided in the Adobe Connect class room in class and as a drop-in clinic on a weekly basis.*

Both the instructor-supplied documents and artefacts such as diagrams and notes, including the resources for project and group management, and those created by the teams, were managed by the groups in their repositories and meeting rooms, with their presence and form persistent so those spaces could reflect the team's way of working. The resources were provided in UML and Markdown format, so they could be easily copied and adapted to work within the GitHub environment. An example of some of the resources provided in each group's repo is shown at Table 3. Conceptual scaffolding for the task, as well as for group processes, modelling, and the GitHub environment were also provided in the unit's LMS site and included video guides, free interactive training materials, academic articles, and templates at beginner, intermediate and advanced levels. A full list is at Appendix E.

Table 3: Selected examples of scaffolding resources provided in each group's GitHub repo.

Template	Intended purpose
Meeting-Knowledge-Template.md	Scaffolding for group regulation and Markdown
branching-demo.md	Scaffolding for shared knowledge object editing workflow, Markdown and UML
multiPAL-use-case.md	Scaffolding for the UML modelling suitable for Use-cases.md and Markdown
whats-my-graph.md	Scaffolding for selecting and developing the appropriate model type for each element, UML and Markdown.

Students were encouraged to structure their collaborative work using the provided tools and templates. A first task for each group in was to create a model of how their collaboration would work, which could include specific roles which could be negotiated within the team. While this approach was scaffolded, it was not mandatory or monitored.

During the teaching session, the researcher was able to respond to learner feedback about the environment by attending classes and hearing where participants were experiencing problems with either tools or task. To make sure this knowledge was accessible, they created a wiki in the whole class GitHub site and the lecturer and/or they addressed each question or problem with a short explanation and links to worked examples and/or video resources. An example response to a question from one team asking for detailed steps to complete the first task is at Figure 14.

Week 6 breakdown

This first week focuses on setting out how each team will manage workflow of ideas and decisions for the group project.

An Issue has been raised for each team, where the deliverable is to adapt a PlantUML model to represent how you (currently) plan to manage distributing the activities you will be doing within your group project. **This is likely to change several times over the course of semester, so spend only enough time on it for it to be clear and useful.**

There are templates ranging from simple to complex: Simple: branching-demo.md Intermediate: example-shared-approval-workflow.md Thorough: example-detailed-shared-approval-workflow.md Complex: roles-and-responsibilities.md

An example of what you might do is to modify the branching-demo.md template which looks like this:

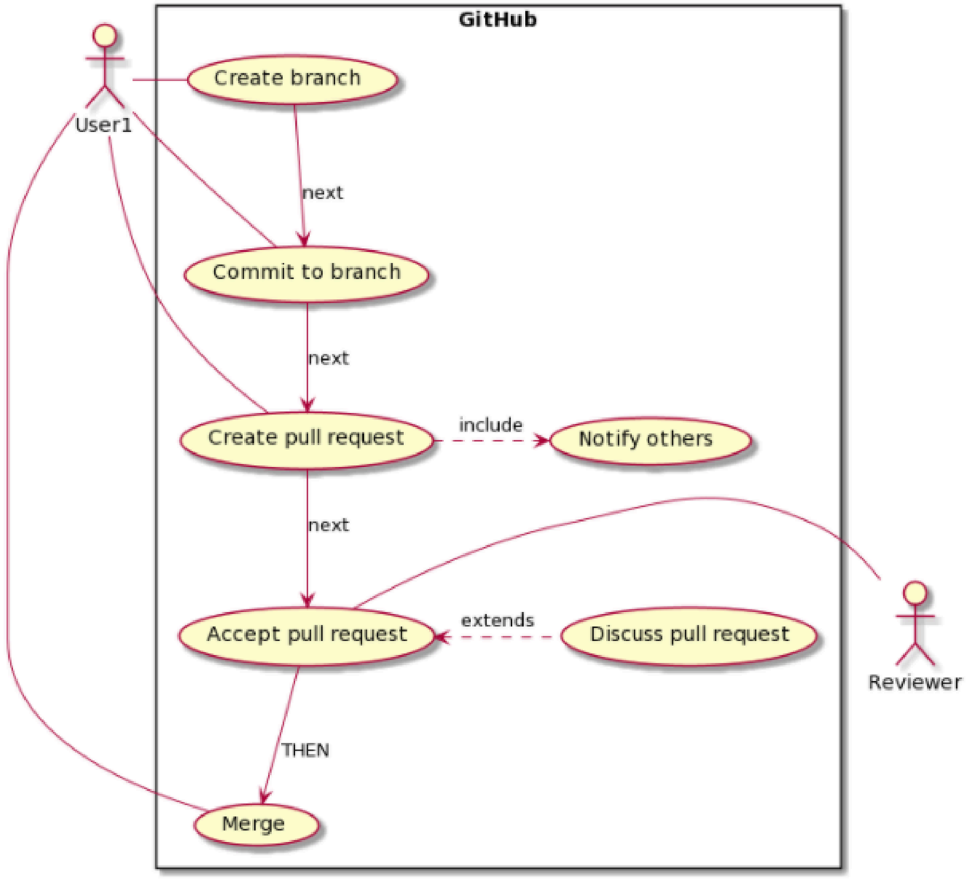


Figure 14: Partial screen shot of Week 6 breakdown wiki page illustrating instructor response to question.

4.5. Data collection

This research collected four types of data relating to student actions and interactions: (1) GitHub asynchronous interaction data, (2) assessable shared knowledge objects, (3) group meeting notes and (4) team process documentation. The interaction data allow the researcher to gain insights into the individual and shared activity the learners engaged in in relation to the shared knowledge objects to establish in what way agency might emerge. The shared knowledge objects show each development made by the group in the process of their model co-construction, the expression of individual to collective knowledge, and the unfolding of that knowledge over time to understand whether patterns of behaviour associated with agency manifested. The team meeting notes and process documents provide information about each group's self-reported synchronous activities and workflows for comparison against the asynchronous interaction data and knowledge objects.

An important consideration in this study is the limited number of participants. The data collection and analysis methods have been designed to gain as much insight into the participants' intentions as possible through thematically classifying all activities based on the content of each action and interaction. The GitHub data allows exploration of the relationship between team knowledge objects and learner interactions, as well as how the learner interactions are themselves related. This contextually-situated reading allows more inference about the communication to be constructed than if we were to use either the document trajectories or team interactions alone. Testing these inferences against the additional data sources which are also connected to them in space and time can establish a level of confidence in their representativeness within this study. As the volume of interaction data was substantial, and the details of the collection and preparation process somewhat technical, the body of this thesis focuses on the data interpretation and analysis. More complete descriptions of the GitHub data sources are at Appendix F, and extended descriptions of the participant interactions are at Appendix H.

A discussion of the relevance of each specific data type follows.

4.5.1. GitHub asynchronous interaction data

As a research technique, systematic observation has the advantages of providing insight into interpersonal behaviours in context and on a temporal continuum. Where traditionally studies of collaboration in higher education use observations of synchronous processes, in this study our observations are conducted by analysis of asynchronous interaction data. This analysis will be used together with the knowledge object development trajectory to answer the research questions.

GitHub data was automatically captured in the university's system in the ordinary course of the students' work on their collaborative project. The data that was captured related to versions of the knowledge objects that students were creating, for example, an update to a use-case model, to interactions around those knowledge objects, for example, a Pull Request to have that update added to the master branch of the group's GitHub repo, and to actions or interactions that were not related to a specific knowledge object, for example, a discussion on whether to use the term 'depository' or 'repository' across the models that a team were developing. GitHub data collection took place after the end of the teaching period, after all work was graded and returned, and all administrative processes completed.

GitHub contains sophisticated software development and workflow features which are not superficially obvious and not all enabled in this university's Enterprise deployment. Key terms used in the following chapters are *Issues, Pull Requests,* and *comments,* which are all communication and workflow mechanisms within the platform, and *Commits*, which are saved changes to a knowledge object. A full list of action and interaction types, terminology and a technical discussion of the procedure for collecting data through the command-line and the Graphical User Interface (GUI) is at Appendix F.

After each team's GitHub repo contents and interaction data was downloaded from the university's system, it was uploaded to the university's Research Data Store and a copy made on the researcher's local computer for coding and analysis. The repos remained available live on the GitHub server for use by the researcher during the analysis process.

4.5.2. Assessable shared knowledge objects

Each iterative version of each document was identified from the GitHub Commit data above, and a link to that version associated with the relevant GitHub action or interaction. Each document could contain multiple narratives, model code, and model diagrams constructed in UML embedded in the Markdown file as shown at Figure 15.

Use Cases

Use Case 1 - Macro Level

The *educator* inputs the course requirements into the AI engine. The AI engine stores, retrieves and modified learning designs and courses via the cloud based data-store and automatically compiles a course. The finished course design is uploaded to the Run time environment. User interactions are in the runtime environment are tracked by the AI engine. This data is used to adapt and modify the learning design to enhance future learning. The *educator* monitors, customizes and facilitates learning in the runtime environment. *Learners* have access to the run time environment to conduct customized learning. The *learning designer* uploads learning patterns, learn designs, and pedagogy principles as a starting point for the system. The *learning designer* should also be able to interact with the AI to support modification to learning designs and pedagogy principles for future use. The *system designer* maintains and provides user support for the AI engine, cloud based data-store and run time environment.


```
@startuml

title Macro Level Automated LDE


rectangle Automated_LDE {
    (AI Engine)
    (Runtime Environment)
    (Cloud based data-store)

}
Learning_Designer --> (AI Engine):Support modification to learning designs and pedagogy principles
Learning_Designer --> (Cloud based data-store):Upload learning patterns/learning designs/pedagogy principles
System_Designer --> (AI Engine):Maintain and provide user support
System_Designer --> (Runtime Environment):Maintain and provide user support
Learner --> (Runtime Environment):Access and customise learning environment
Educator --> (AI Engine):Input course requirements
Educator -->  (Runtime Environment):Monitor customise and facilitate learning environment
(AI Engine) <..> (Runtime Environment):Upload courses and track user interactions
(AI Engine) <..> (Cloud based data-store):Store retrieve and modify learning designs/courses

@enduml
```

Figure 15: Partial screen shot illustrating narrative, diagram and code elements included in each Markdown document.

A list of document versions were printed from GitHub to PDF, uploaded to the university's Research Data Store and a copy made on the researcher's local computer. The iterative versions were viewed on the GitHub server during the analysis process and are also accessible in the downloaded repo history.

4.5.3. Group meeting notes and process documents

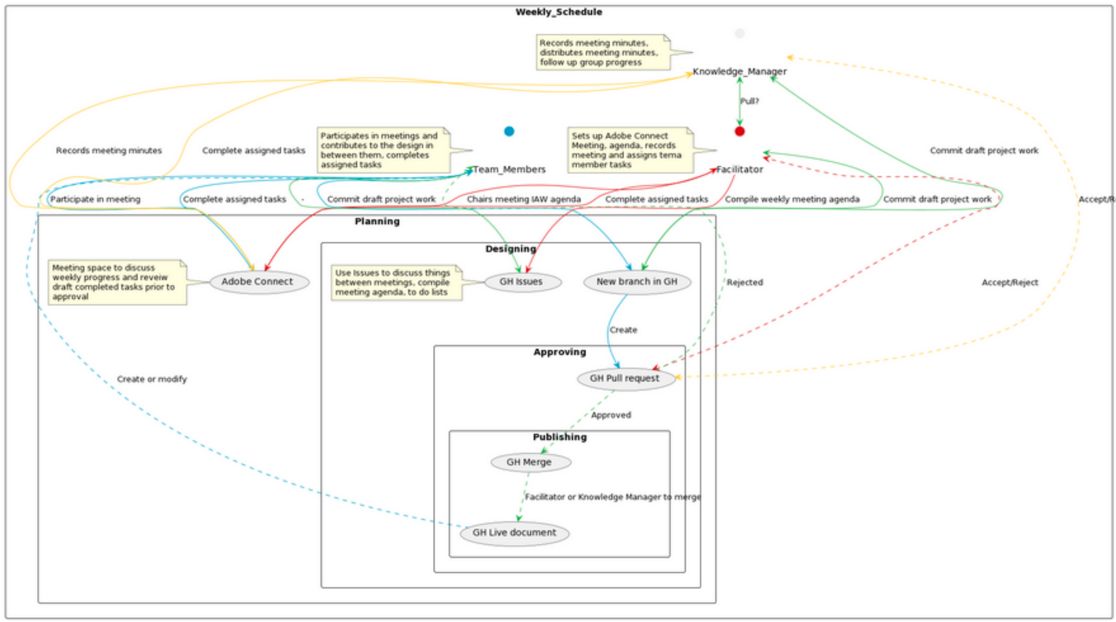
In the absence of an interview, a second researcher or other established validation mechanism, the issue of reliability was partially addressed by using the group's process documentation as a second view of the way in which each group collaborated. Convergence of data from two or more sources can strengthen the credibility of research findings (Yin, 2015).

Each team used templates in their repo to create meeting notes as Markdown files, plus a document containing a model of their workflow, *Processes.md*, one containing a description of their workflow, *Contributing.md*, and another with reflective comments about their collaboration, *Insights.md*. The *Insights.md* document was not part of the assignment description but was mentioned in class as a way for each group to reflect on their collaboration in preparation for the individual reflection task. The iterative versions of these were uploaded to the university's Research Data Store and a copy made on the researcher's local computer for coding and analysis. Workflow models are represented by a graph generated by PlantUML code, followed by the code itself, embedded in the Markdown file as shown at Figure 16.

200 lines (170 sloc) | 6.61 KB   Raw   Blame

Holistic design and collaboration processes

This diagram represents the holistic design and collaboration processes that will be utilized by our team to design and deliver this project within Github. Within this diagram, the roles and respoonsibilities of each team member are outlined as well as how we will collabotate to contribute to our repository.




```
@startuml

        skinparam {
                wrapWidth 200
            ActorBorderColor #FFFFFF
            packageStyle rectangle
}

rectangle Weekly_Schedule {
```

Figure 16: Partial screen shot from Team A's repo showing a UML workflow model.

4.6. Data analysis

There is increasing interest in the way in which content and process data from CSCL systems can be use in analytic approaches for educational design and research (Trausan-Matu & Slotta, 2021). This study draws from the Theoretical Framework set out in Chapter 3 to take a sociocultural stance appropriate to the trialogical learning design, and follows other studies in this tradition in using qualitative content analysis of both participant actions and interactions and changes to knowledge objects as its main method (Uttamchandani & Lester, 2021). As well as addressing the need to replicate existing studies (Janssen & Kollar, 2021) this approach also progresses research into how a novel CSCL environment and data collection method can be designed to facilitate research into collaboration. There are both theoretical and inductive components to this analysis.

A thematic approach to content analysis was identified as being appropriate to the study because it can accommodate both theoretical and inductive approaches across the same data, is flexible enough to be used by other researchers with varied epistemological and theoretical views, is compatible with the sociocultural theoretical perspective and is viable within the scope of work for a single novice researcher (Braun & Clarke, 2006). As naturalistic forms of inquiry reflect participants' multiple realities, additional steps need to be taken to ensure trustworthiness (Lincoln & Guba, 1985). Credibility can be increased by prolonged engagement, persistent observation and triangulation (Lincoln & Guba, 1985). The first is addressed in this study by the project-based nature of the work and continued engagement by the researcher in providing technical and task support to the participants as set out at Sections 4.3 and 4.4 above, the second by the analytical process identifying actions and interactions over time as explained in Section 4.9, and the third by verifying the tentative results of data analysis by conducting the same analysis on an additional data source as discussed at Section 4.6. While there is still a risk to credibility, the findings are not considered generalisable and will not be used to develop a new theory, but link to the theory adopted in this research.

4.6.1. Analysis framework for epistemic agency

The theoretical component of our data analysis is informed by previous studies in knowledge building environments discussed in the Literature Review and Theoretical Framework chapters. As the study aim is to progress research on the observation of agency in project-based CSCL work in higher education, it is important for the analytic process to be consistent with similar studies. In educational contexts, schools rather than universities tend to be the site for studies on both knowledge building (Moss & Beatty, 2006; Zhang et al., 2009) and agency (Hakkarainen et al., 2004; Palonen & Hakkarainen, 2000; van Aalst & Chan, 2007). However, research by Damşa et al. (2010) discussed in the Literature Review Section 2.5.2 and in the Theoretical Framework Section 3.5 established a theoretically-grounded framework for understanding epistemic agency in trialogical and knowledge building settings for university project-based collaboration. While their work was specifically in relation to shared epistemic agency (Damşa, 2014; Damşa et al., 2010; Damşa & Ludvigsen, 2016), the underpinning conceptual base of deliberate efforts of groups to co-construct shared knowledge objects, and the coding schema (Damşa et al., 2010) have also been applied to individual actions in the context of collective discourse to identify how epistemic agency emerges (Damşa, 2014). Both individual actions and collective trajectories of interaction are quantitatively as well as qualitatively categorised to understand the connection between individual and group activity contributing to the development of shared epistemic agency (Damşa, 2014). This framework of actions indicative of shared epistemic agency and collaborative knowledge creation informs the thematic basis for analysis in this study. It is set out in more detail in Section 4.7.1.2, with examples of the activities assigned in each classification, at Table 13.

The need for an additional inductive component is driven by the novelty of the data type and the naturalistic inquiry principle of persistent observation to be open to multiple influences and contextual factors during the study (Lincoln & Guba, 1985). While it is impossible to completely avoid researcher bias, using a data-driven approach to identify emergent themes provides a useful foundation for further research into the use of GitHub collaboration for knowledge building.

4.6.2. Levels of analysis

The need for further research on the relationship between different levels of agency (Cress & Kimmerle, 2018; Damşa, 2014), and for exploring the interactions around artefact production and the development process (Trausan-Matu & Slotta, 2021) through multi-level analysis (Cress & Kimmerle, 2018) informs the two stages of data analysis.

The first stage analyses the frequency and type of actions and interactions of individual participants by coding them as *epistemic*, *regulative*, or *other*. This identifies manifestations of agency that can be observed at individual level. The individual actions are also analysed in the context of their group, to construct a set of conjectures about typical group behaviours in relation to each category of epistemic action. This creates an understanding of the key characteristics of each group's collective activity in relation to each activity classification. These conjectures are then subject to a validation process through triangulation as described in Section 4.6.3.

The second stage uses the findings from the first stage together with a trajectory analysis of each group's collective activity over time and iterative changes to knowledge objects to investigate the connection between activity and knowledge object advancement. This identifies manifestations of shared epistemic agency that can be observed at group level.

4.6.3. Triangulation through secondary data sources

As well as the GitHub interaction and artefact data, this framework will also be applied to secondary data sources to improve trustworthiness. As the study was conducted by a single PhD student with no inter-rater check on the asynchronous data classification and analysis, it is necessary to test the findings against a more independent source to establish credibility (Lincoln & Guba, 1985). To address this weakness in the research, the self-reported processes of each group found in their synchronous meeting notes and process documents are also classified and analysed to improve reliability and validity.

4.6.4. Summary

To understand what kind of agency emerges in project-based university group work in the GitHub environment at individual and collective levels, action and interaction data from the environment is thematically analysed using a coding system developed to classify activity into categories of epistemic agency, with an inductive component to allow for emergent themes. The relationship between the theoretical framework and analytic methods is set out at Table 4, with the data analysis model illustrated at Figure 17 following.

Table 4: Framework for data analysis.

Conjecture	Theoretical foundation	Analysis	Data
Stage 1: epistemic agency emergence and observation – individual level			
Purposeful and progressive discourse and coordination of personal ideas with each other helps realise epistemic agency. Individual and joint actions contribute to shared goals.	Creation of shared knowledge objects is central to collaboration (Damşa, 2014; Damşa et al., 2010; Damşa & Ludvigsen, 2016; Paavola & Hakkarainen, 2005, 2014). The characteristics of the collaboration frame the conditions for emerging agency (Damşa, 2014; Damşa et al., 2010). Co-constructing knowledge requires active individual and collective contributions (Damşa, 2014).	*Interactions / actions at individual and group level as units of analysis* - qualitative content analysis of the interaction data and knowledge objects to identify characteristics of individual and joint actions (Damşa, 2014). *Interactions / participation at individual and group level as unit of analysis* - quantitative analysis of the interaction data to establish whether there is an association between level and extent of participation and productive interactions in relation to the knowledge object (Damşa & Ludvigsen, 2016; Isohätälä et al., 2017; Panadero & Järvelä, 2015). *Interactions / participation at individual and group level as unit of analysis* - quantitative analysis of the interaction data to establish whether there are observable differences in frequency, type or object of interactions (Damşa, 2014).	GitHub comments, Commits, Issues, Pull Requests GitHub interaction logs GitHub documents: Project documents *Components.md* *Interactions.md* *Use-cases.md* *README.md* ad hoc documents Process documents Meeting notes *Contributing.md* *Processes.md* *Insights.md*
Stage 2: shared epistemic agency emergence and observation – group level			
Productive interactions lead to changes to the knowledge object Deliberate and sustained effort results in materialisation of new knowledge	Productive interactions involve sequences of collaborative actions that advance the knowledge object (Damşa, 2014; Damşa & Ludvigsen, 2016). Shared coordination of actions and contributions to the joint venture at group level enables shared epistemic agency (Damşa et al., 2010). Shared epistemic agency enables deliberate, joint, object-oriented interaction (Damşa, 2014).	*Trajectories of Interactions / actions at group level as unit of analysis* - qualitative content analysis of the interaction data together with knowledge objects to identify sequences of collaborative events that lead to productive changes in the knowledge object (Damşa, 2014).	GitHub comments, Commits, Issues, Pull Requests GitHub interaction logs GitHub documents: Project documents *Components.md* *Interactions.md* *Use-cases.md* *README.md* ad hoc documents

As this analysis is conducted on a novel data format from a novel environment, and intended to extend the research field in this new direction, there is a strong element of exploration in the analysis procedure which is set out in detail in Sections 4.7 and 4.8. To skip directly to a summary of the analytical process, see Sections 4.7.3 and 4.8.2. Results are in the following chapter.

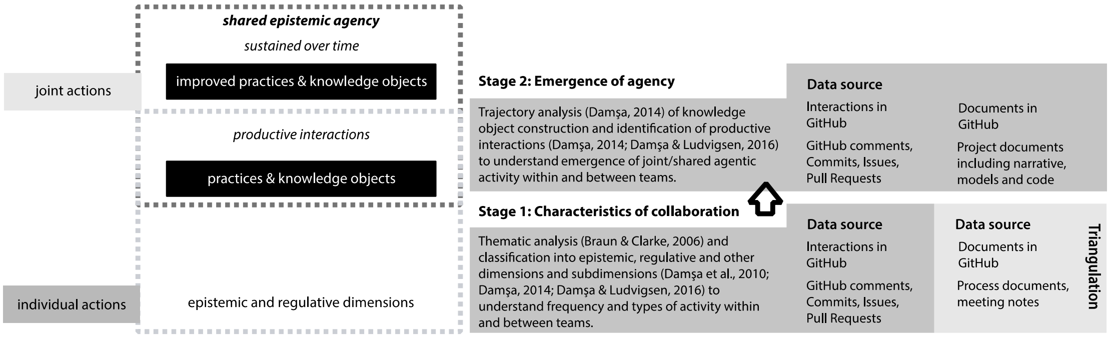


Figure 17: model illustrating relationship of data types of analytical concepts.

4.7. Analysis procedure: Stage 1

To answer Research Question 1, analysis was conducted in two stages. This section describes Stage 1, which answers sub-question (a), and provides data toward Stage 2, which answers sub-question (b). Stage 2 is described in Section 4. In Stage 1, each set of GitHub data was coded using the scheme in Table 13. Where data did not fit the existing framework, new categories were developed. From this, a series of conjectures was developed about the characteristic features of each team's collaboration based on the types of individual and joint actions that were predominant in each group's work.

Next, each group's synchronous meeting notes and process documents were coded using the same classification scheme. The combination of individual and joint actions identified in these data were compared with the conjectures that resulted from analysis of the asynchronous data to construe to what level those conjectures could be supported, and a revised set of conjectures developed.

4.7.1. GitHub asynchronous interaction and action data

The process generally followed the six phases of thematic analysis established by (Braun & Clarke, 2006). Each phase is described below in Sections 4.7.1.1-4.7.1.6.

4.7.1.1. Familiarising yourself with your data

It is important for a researcher to immerse themselves in the data through active and repeated review, regardless of whether initial analysis themes have been established (Braun & Clarke, 2006).

After the interaction data was downloaded from GitHub using the combination of command-line scripting and printing from the group repos accessed using the GUI described in Section 4.5.1 and Appendix F, events were organised chronologically and associated with a specific document version where the action was document-related. A preliminary analysis indicated that the data was conceptually compatible with the theoretical framework and research method, and that the individual and group asynchronous interaction was visible, complex, and informative.

However, the various ways in which communications can occur asynchronously in GitHub means interactions were different to those kinds of utterances that were the subject of the previous studies on shared epistemic agency. GitHub interactions could be more like writing a message post, sending a text, or composing an email than real-time conversation. As well as more fully-formed communicative or epistemic content, messages in the GitHub data had a different composition to those that comprise speech acts, and to those that constitute synchronous online interactions such as text chat. While some contained either no or default information, others contained salutations, structured contents and valedictions, as if they were an email or letter, and their persistent form also allowed their use as resources for shared understanding. This led to some questions as to how these interactions should be coded for analysis.

Previous studies using Damşa et al. (2010)'s theoretical framework and classification system used the combination of qualitative data to apply the lens of activity trajectories (Lemke, 2000, 2001), 'zooming out' from single utterances to focus on longer sequences of interaction instead of the micro level that might ordinarily be the subject of a conversation analysis (Braun & Clarke, 2006), and in Damşa (2014), while the observation of sustained activity was still important, they also 'zoomed in' at individual interaction level. The question was then whether interactions should be coded at the word, sentence, message, or other level.

As the analytical objective is to observe an emergent phenomenon it is necessary not only to identify whether it can be observed, but also in what way they might be observed. A pattern or series of actions can only be identified if there is data at the individual action level that has an identifying label. While Damşa (2014) did analyse data relating to individual activity, other studies on shared epistemic agency did not conduct analysis at statement level (Damşa, 2014; Damşa et al., 2010; Damşa & Ludvigsen, 2016). As Braun's view is that coding be applied to the most fundamentally meaningful unit that can be investigated in relation to the phenomenon of interest (Braun & Clarke, 2006), and GitHub events comprise discrete data points, interactions were coded at GitHub event level, for example, a Commit or comment action.

Data organisation

Data was organised in a series of stages. First, the GitHub data extracted by command-line calls was downloaded and converted to CSV for manipulation in a spreadsheet application. The content of each data field was reviewed and the set of fields for analysis determined (see Appendix F for more details). The fields were then consolidated into a format where there was a similarity between the information despite different fields being available in different events types, as shown at Table 5.

Table 5: Example of the different fields associated with event types in GitHub data output.

Event	Reference	Field	Field 2	Field 3
Commit	sha	Commit/message		
Issue event	ID	Issue/title	Issue/body	Event
Comment	ID	Body	Issue URL	
Pull Request	Number	Title	Body	
Issue	Number	Title	Body	

This resulted in the final set of actions and interactions for analysis. While there is a full description of GitHub actions in Appendix F, the actions that were analysed for this study are the different *comment* types, in which participants added a note either to an existing note or to a document, *Commits*, which comprise saved changes to a document, *Issues*, which are threaded discussions which may or may not be connected to a document, and *Pull Requests,* which are like *Issues* but function as workflow requests to save an edit to the shared document to create an updated version. Table 6 below lists the total of each type of GitHub interaction, including system-generated actions, by team.

Table 6: Breakdown of all GitHub actions, interactions and assessable knowledge objects for analysis for all team members by team.

Action/Interaction Type by Team	A	B	C	Total
approval comment		7		7
assigned	50	39	89	178
closed	52	75	87	214
Comment	85	114	278	477
Commit	241	203	310	754
head_ref_deleted	8	4	12	24
head_ref_restored	1	1		2
Issue	41	65	81	187
labeled	1	1	1	3
mentioned	28	32	321	381
merged	25	46	50	121
milestoned	1	1	2	4
PR Comment		11		11
Pull R	29	50	58	137
referenced	25	62	66	153
renamed	2		3	5
reopened	8	1	1	10
review comment		12	3	15
review_requested	46	102	141	289
subscribed	28	32	321	381
unassigned		3		3
unlabeled		1		1
Total	671	862	1824	3357

The documents which were analysed are the assessable knowledge objects that are the focus of the group project. Table 7 lists the assessable knowledge objects that the teams produced in the course of their project.

Table 7: Assessable knowledge objects produced by each team for the project.

Assessable Knowledge Objects by Team	A	B	C	Total
Components.md	1	1	1	3
Interactions.md	1	1	1	3
README.md	1	1	1	3
Use-cases.md	1	1	1	3
Task-based knowledge objects	4	4	4	12
An intergrated learning environment - Readin	1			1
Mod4L-Final-Report-summary.md	1			1
Using-IMS-summary.md	1			1
Design critique template	1			1
Design critique.md		1		1
Definitions.md			1	1
Other documents created by each team	4	1	1	6
Total Documents	8	5	5	18

Each action, interaction and document modification was associated with a teaching week and day to provide an overall structure, although this structure was not rigid, and both tasks and interactions overlapped these boundaries. A local time was calculated for each event as there is an inconsistency between the GUI displaying local time and the server using UTC, and, unfortunately, the data views offer differing levels of granularity with the GUI specific only to day rather than date or date and time level. However, the GUI view offers true temporal sequence, with the data accessible by command-line not sensitive to the order of events when they occur close together. This allowed an evaluation of whether students were probably working together in class in synchronous team meetings as opposed to their asynchronous interactions.

The data was then processed in two phases, beginning with the smallest dataset as a procedural test. A hyperlink to the relevant document version was added to each event, and each the document and its 'diff' (the view that shows which changes have been made in the current edit) reviewed in GitHub to capture a sense of time and context.

4.7.1.2. Generating initial codes

Theoretical component

The theoretical component of my coding was informed by general descriptions of characteristics of collaboration (Damşa et al., 2010) and specific classifications of action developed to describe the indications of epistemic agency (Damşa, 2014; Damşa et al., 2010; Damşa & Ludvigsen, 2016) set out in Section 4.6.1 above. The inductive aspect evolved through annotation, without attempting to resolve tensions or inconsistencies within the data (Braun & Clarke, 2006). More discussion on the inductive coding process is at Section 4.7.1.3.

In the first pass through the first set of data, each Commit action was reviewed and given a short description and a potential assignment to the epistemic, regulative or other classification based on the content of the action or interaction, with reference to the detailed descriptions of behaviours contained in the reference studies for guidance (Damşa, 2014; Damşa et al., 2010; Damşa & Ludvigsen, 2016), and annotations where further consideration was necessary. The process was repeated for Issues, Pull Requests, and comments. Automated system events types such as referenced did not need classification as they were automatically generated when a branch was merged to the master, so while they were retained they were not coded. Other system event types such as mentioned and subscribed were related to the collaborative process; this event is auto-generated when a user mentions another user with the '@' symbol preceding their handle, so it does have a contextual meaning. But it is unlikely to have a contextual meaning outside the broader communicative intention of the message, so does not require separate coding. The events assigned and review_requested could be seen as being inherently – and differently – encoded already. This process was repeated with the second dataset before reviewing the whether the process was a good fit for the data so far.

Methodological issues

The first issue that arose was a high level of duplication in the data. As teams used the workflow processes not always systematically, in some cases a Commit was saved directly to the master branch, and in other cases it had both an Issue and Pull Request (PR) associated with it, and all of those may have had some kind of communicative interaction attached. In many cases, these were identical. However, in some cases they were not. For example, at commit 378ca03[9] the comment is "I've fixed the display of the image and some typos. I've also changed the title to a Use Case scenario, as it's very big picture, not micro level info for the software designer as to what happens when." where the associated issue comment 1352 is "hi [B5] I've fixed the uml so it displays in the system properly. I changed the name to Use case Scenario- as it's very big picture, so instructions re interaction system & human. Do we need that level of detail also? that would be quite long & intricate- I'm not sure.". In an effort to cast a wide interpretative net in the first instance, all the data was retained to be addressed in the next stage of analysis.

The next concern was to ensure that the descriptions of each action and interaction were as consistent as possible, so that these could be tightly aligned with the classification schema to increase coding validity. This was achieved by constructing a syntax for descriptions based on the actions that the students were engaging in in their collaboration, in the task, and in their environment, as set out in Table 8.

9 Individual interaction references will be used in this chapter to pinpoint classification examples, but in the interests of readability will be redacted in the Results chapter. In this section, comments have a four-digit identifier, commits a seven-character identifier, Issues and Pull Requests have a team identifier, followed by a "#" symbol and the Issue or Pull Request identifier. Pseudonyms for each team member begin with their team identifier, for example, A1. Where the team member is referred to directly in communication, their pseudonym is enclosed in square brackets.

Table 8: Standard description syntax developed for actions and interactions after first pass through datasets for Team A and Team B.

Part	Verb	Object	Location	Contextual information
Form	Simple present tense	Target	Reference number or description	Additional comment useful in locating or contextualising the change
Example	*Add, edit, rename, fix*	*Narrative, code, diagram, meeting notes*	*Sequence Diagram 1, intro narrative for collaboration*	*After agreement from other team members*

These re-worded actions were then reviewed for appropriateness in relation to the classification schema and consistency of categorisation across the dataset. An example of four actions and the alignment of these with the epistemic and regulative dimensions of activity (Damşa et al., 2010) is at Table 9. While Commit events generally had a single document, and often a single idea or focus, the affordances of the asynchronous environment led to communicative interactions which frequently had both regulative and epistemic intention and content, and another decision point in the analysis process. An example of this is Commit b68eab0: “I had to copy & paste the branch back into the master- couldn't work our easier way. This is now incorporating all our changes”, where B4 is sharing knowledge about how to use the environment as well as reporting what’s been done to incorporate everyone’s work and the location of the current version of the knowledge objects. In a traditional group work environment, this activity would not have been reported at all, as document updates are generally performed in isolation and the process knowledge is not shared. In a synchronous voice or face-to-face environment if the process was being observed, it is likely that the information would have been provided in separate utterances, if both were considered necessary, as the demonstration of the work may have negated the need for the second part of the message. The question in relation to this study is whether this interaction should be classified as epistemic, regulative, or another category of coding, for example, a blended classification.

Table 9: Examples from the data illustrating the kinds of actions and interactions that were categorised in the epistemic and regulative dimensions.

type of action/interaction	ID	GH commit_event	GH_event_comment	epitemic classifications	regulative classifications
commit no comment	9ebea28	Update Roster.md			[edit roster to add meeting]
commit with comment	4a9c69e	Update Component #2 Changes based on critique from meeting 30/04/19. - Added controllers that were missing		Update Component #2 Changes based on critique from meeting 30/04/19. - Added controllers that were missing	
Issue comment	1163		Hi Everyone I've updated the meeting notes, readme and contributing docs. I've assigned everyone Issues based on our meeting last night. The aim is to complete this weeks tasks by Friday, due to semester break, if that's possible. FYI- I'm away for Easter (Thurs afternoon - Mon) with no internet, so will check back in with everyone on Tuesday.		[notify team of work done and that tasks have ben delegated and have timeline]
Issue	86	Course Design with Smart Functionality	Thought I would put this up for discussion. I ended up doing a use case without AI as an actor because it didn't need to be. What if the entire LE has smart functionality, as stored user data and made decisions within the platform without an other actors interfering? What if a CD and COP only added to the repository? So was able to elevate the experience by providing more resources for AI to read from? I think this is a good start but could be expanded upon. Especially if Daniela has her own ideas coming out of the research she has done. Let me know of your thoughts.	[discuss new use case idea in context of new concept and others' research, ask for input]	

Going back again to the foundation study's decision to not analyse data at the statement level (Damşa et al., 2010), it made sense from both a methodological alignment and a data coherence point of view to consider each action and event, and each communication, as a bounded unit with a single classification based on the inferred intention of the activity. While this does not allow sufficient consideration to capture the full complexity that is contained within each one, it is a manageable approach for a single researcher or instructor, and more easily adaptable to machine or other automated processes should that be useful in future. Based on the letter-like form that many messages in the interaction data took, it's likely that the learners thought of each one as a unit too. The intention, where not explicit, was inferred though contextual information about the timeline within the overall scope of the project, the location within the Commits, Issues and Pull Requests, and the content of the knowledge object and the associated communication or lack thereof. In the example above at Commit b68eab0, while there was information about the process shared, it was informational at a fairly superficial level, and didn't include options that had been considered and discarded, or a request for help from another team member before the action was taken. For that reason, it is likely that it was intended to be a general heads-up to the team about what had happened to the knowledge object rather than instructions on how to fix problems with updating the master branch. For that reason, it is classified as *regulative-6-monitoring process*.

Classification examples

Following this consideration, the remaining data was coded. Examples of both Commits and comments from the epistemic and regulative dimensions are below.

An example from the epistemic category is Commit fdd7520. In this action, A1 adds a paragraph to the Interactions.md document describing the *Student – Sequence Diagram* model, a key concept development classified as *epistemic-4-elaborating concepts/ideas*, as it builds on knowledge work by reverse-engineering it (incompletely) back into narrative that contains the intention of the model and system it describes. A screen shot illustrating that action is at Figure 18.

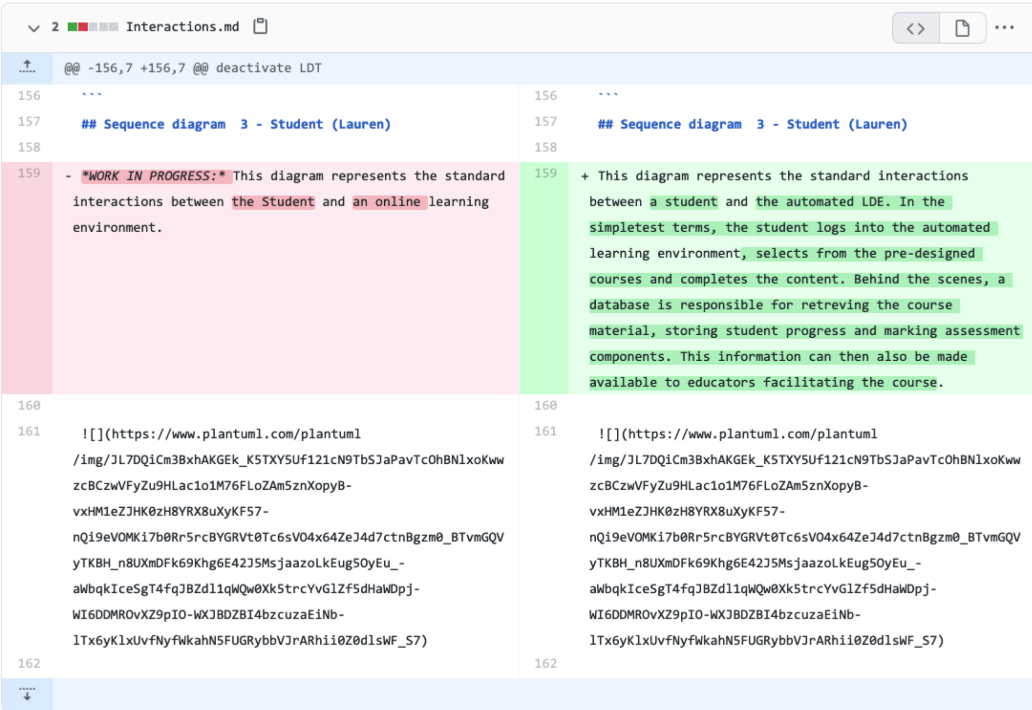


Figure 18: Screen shot illustrating an epistemic action on Interactions.md made at Commit fdd7520.

An example from the regulative category is Commit 9daf5e8, illustrated at Figure 19. In this action, A1 adds a line to the Insights.md document noting that a section of the document is yet to be completed, and the name of the team member to whom is has been assigned. This is classified as *regulative-6- monitoring process-evaluating progress and outcomes*, as its purpose is to provide a reminder and placeholder for the whole team as well as the contributor themselves.

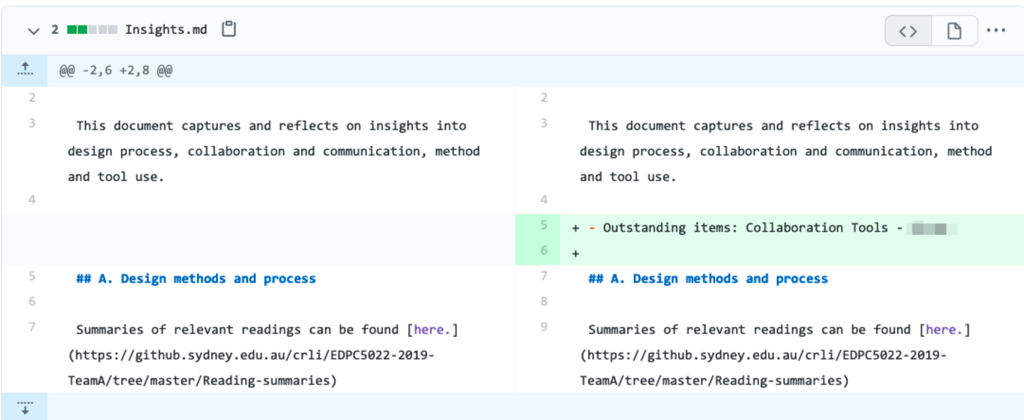


Figure 19: Screen shot illustrating a regulative action on Insights.md at Commit 9daf5e8.

An example of a communicative interaction in the epistemic category is comment 1049 below at Figure 20, where the discussion is around the model structure, and the suggestion of what might be possible in future learning design.

Figure 20: Partial screen shot illustrating a communication in the epistemic category at comment 1049.

An example of a communicative interaction in the regulative category is Commit 07cfa39, where the conversation focuses on the technical editing of the *README* file shown at Figure 21.

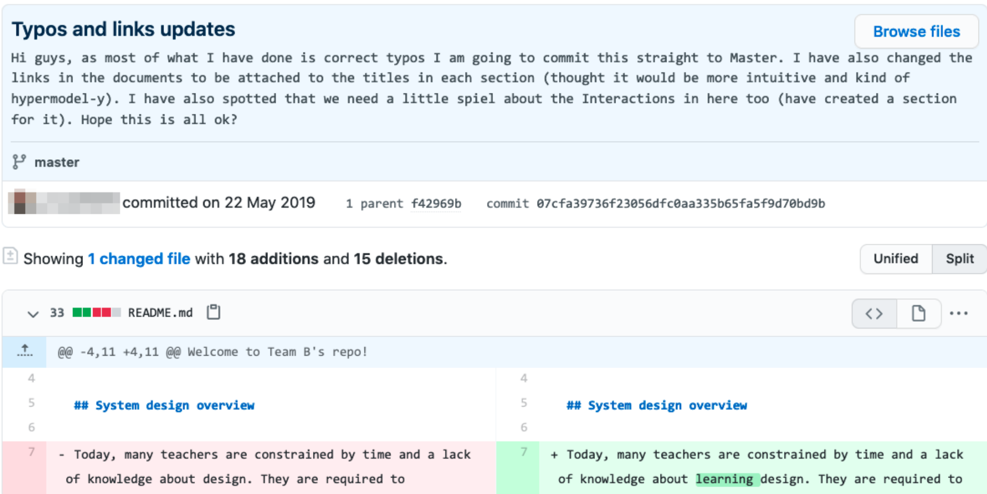


Figure 21: Partial screen shot illustrating a communication in the regulative category at Commit 07cfa39.

Unlike changes to knowledge objects, solely communicative interactions could also have a purely relational purpose, as in Figure 22 below.

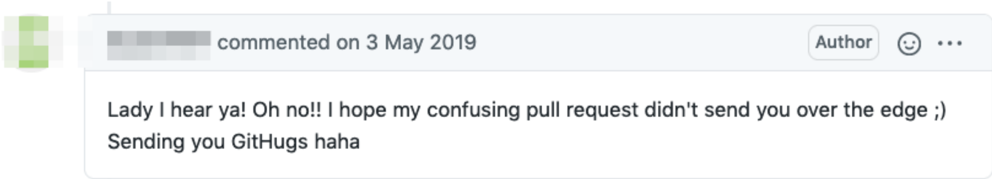


Figure 22: Partial screen shot illustrating a communication in the relational category at comment 1347.

4.7.1.3. Searching for themes

After data has been initially organised and coded, the analysis becomes re-focused at the level of themes rather than codes (Braun & Clarke, 2006). While the theoretical component of coding came with pre-established themes, as an exploratory study there was an inductive component to the coding where descriptions and annotations became codes and subsequently developed into emergent themes.

Inductive component

As well as content, it became clear that the GitHub communications also had another layer of data which had not been fully anticipated. Some actions had no message at all, or only a default message. But where there were messages, there was a wide variation between the types of communicative elements that performed a social function on top of the epistemic or regulative function. These included whether the comment addressed the team generically, for example, “Hi team”, or a specific team member by their name or tag; the language around proposing contributions, for example “had a go”, or “fixed” something; the use of text-message style punctuation in the form of exclamation marks or emojis; and traditional message forms like a salutation or valediction with the author’s name. Social cues are difficult to replicate in online situations (Isohätälä et al., 2021; Kreijns et al., 2013; Strauß & Rummel, 2021), and as the focus of this study is on communities which are likely to be largely online, and engaging in asynchronous interactions with even further reduced opportunities for non-verbal communication, noting any association between these and the groups’ development of shared epistemic agency could be a useful contribution to the research base.

However, because prior studies on epistemic agency have been conducted in traditional synchronous settings, while there is a coding in the framework for ‘unrelated / social’ interactions, this was not neatly transferable as the message itself typically had an epistemic or regulative purpose. While these interactions had similarities to the asynchronous interactions which were the subject of analysis by Häkkinen (2013), and their questions about participation and the differences between groups are relevant, their multiphase method emphasised different elements to those indications of shared epistemic agency which are under investigation in this study (Häkkinen, 2013). The accessible research on using GitHub for collaboration is silent on this topic (Kertesz, 2015; Longo & Kelley, 2015; Pe-Than et al., 2018; Zagalsky et al., 2015). The field of socially-shared regulation for learning (SSRL) does address group-level social and relational phenomena unfolding over time but focuses on micro-level events in synchronous, and often face-to-face, interactions (Isohätälä et al., 2017; Järvelä & Järvenoja, 2011; Järvelä et al., 2013; Panadero & Järvelä, 2015), with recent research exploring combinations of observational with physiological data (Saint et al., 2022).

A recent manifesto by Isohätälä et al. (2021) has argued that as technologies can disrupt social interactions more attention should be paid to 'social sensitivity', a socio-emotional construct present in the manner of collaboration. The deep complexity of the concept, canvassing a multitude of sometimes conflicting theoretical perspectives (Isohätälä et al., 2021) makes it difficult to apply completely in this project. A single dimension that could be supported by the data emerged as a viable theme, which was the elements in each message that indicated how the author was relating to the recipient/s. Social presence, while again complex, is generally understood to be the degree to which the other in a communication appears to be a 'real' person (Kreijns et al., 2004; Kreijns et al., 2013; Kreijns et al., 2022). Work in asynchronous contexts has viewed the way in which social interaction manifests in CSCL through the lenses of sociability, social presence, and social space (Kreijns et al., 2003; Kreijns & Kirschner, 2002; Kreijns et al., 2004; Kreijns et al., 2013; Kreijns et al., 2022). Traditional measures of social presences such as Short et al. (1976) have been critiqued as lacking clarity as to their definition and theoretical guidance (Albertson, 1980; Kreijns et al., 2013) however the framework proposed by Kreijns et al. (2013) is complex and still building empirical support. Where the workflow processes in GitHub have been designed as social presence affordances similar to those suggested in Kreijns et al. (2003); Kreijns and Kirschner (2002); Kreijns et al. (2004); Kreijns et al. (2013) in that team members can view others' actions and contributions, text-based messages as computer-mediated communications have a relational aspect that influences both task and social interactions (Walther, 1995). While a potential problem with thematic analysis is that the themes do not cohere around the central question (Braun & Clarke, 2006), as the central question of this study is about the way in which epistemic agency might be observed in a novel environment, a new theme that might provide insight into that is an important addition. However, this must be an additional layer of coding rather than displacing the original classification, representing a novel dimension in this analysis.

To appropriately code these messages required an approach that was itself somewhat novel, but still based in a framework which could be meaningfully applied in our context. Where Kreijns et al. (2022) views social presence as a network of related constructs that extend beyond interaction to theories around sociotechnical environments and psychological states, relational presence is a metacommunicative aspect to interaction that focuses on how people “regard each other” (Burgoon & Hale, 1984, p. 193). As a key priority of CSCL research is to understand how learners relate to each other in collaborative environments (Isohätälä et al., 2021), and the content of interactions was the subject of analysis in its own right, using metacommunicative coding that could be applied to text analysis of GitHub interaction data seemed an appropriate approach.

The framework developed by (Burgoon & Hale, 1984) is based in psychometric measures, with 12 relational communication ‘topoi’ identified across anthropological, clinical and psychological literatures. Within these, the principal dimensions are control, affection and inclusion, with the latter two comprising important aspects of intimacy (Burgoon & Hale, 1984). Another aspect of intimacy is the depth-superficiality continuum, which indicate the degree of intimacy which is the (sometimes unstated) objective of the relationship (Burgoon & Hale, 1984). These were further refined to eight dimensions of relational message themes, with control and intimacy continuing to be important themes (Burgoon, 1987 #592}. While language conventions, communication formats and emoji have evolved since this scheme for relational communications was developed (Burgoon & Hale, 1984, 1987), the relational continua can be simplified and adapted for this study. While there is an attempt to theorise the broader meaning of the language and tone as relational, thus latent, coding was done at the semantic level, that is, what is immediately apparent from what has been written without attempting to uncover the underlying reasons (Braun & Clarke, 2006). Table 10 below provides examples of the behaviours associated with the different relational message themes (Burgoon & Hale, 1987).

Table 10: Examples of the behaviours associated with different relational themes.

Theme	Examples
Dominance/ Control	(attempted to persuade me) (did not attempt to influence me) (tried to control the interaction) (tried to gain my approval) (didn't try to win my favor) (had the upper hand in the conversation)
Intimacy I Immediacy/ Affection	(intensely involved in our conversation) (did not want deeper relationship) (not attracted to me) (seemed to find conversation stimulating) (communicated coldness rather than warmth) (created sense of distance between us) (acted bored by our conversation) (interested in talking to me) (showed enthusiasm while talking to me)
Intimacy II Depth/ Similarity	(made me feel similar) (tried to move conversation to deeper level) (acted like good friends) (desired further communication) (seemed to care if I liked him/her)
Intimacy III Receptivity/ Trust	(sincere) (interested in talking) (wanted me to trust) (willing to listen) (open to my ideas) (honest in communicating)

Each message was reviewed against these indicators of relational theme, and coded as having low, medium or high relational presence (RP) based on the alignment of the message components with these indicators. The number and type of indicators differed depending on the different components each message contained, with some indicators appearing multiple times in a single message, for example, a name/handle in both salutation and valediction, or both an inclusive 'us' and friendly emoji. The overall message coding was based on both the presence of Low, Medium, or High RP indicators, and the balance of these indicators in the message overall. For example, a message opening with 'Hi' but having no other High RP would be rated as Medium or Low depending on other message elements. Examples of how the message elements were classified is illustrated at Table 11 below.

Table 11: Examples of message components that contributed to the classification of having low, medium or high relational presence (RP), adapted from (Burgoon & Hale, 1984).

Theme	Low RP	Medium RP	High RP
Intimacy II Depth/ Similarity	Hi/Hey	Hi/Hey	Hi/Hey
Intimacy II Depth/ Similarity	All Guys/Team	Guys/Team	Name or Handle
Intimacy I Immediacy/ Affection	Someone/ Everyone	I/You	We/Us
Intimacy III Receptivity/ Trust	Fixed (closed) Done.	Drafted (let me know if changes) If everyone's happy.	Had a go (open to feedback) Do you think?
Dominance/ Control		Thanks	Thanks!
Intimacy II Depth/ Similarity		Name or Handle	Name or Handle
Intimacy I Immediacy/ Affection			Emoji ☺

Coding conventions

Where a Commit action had communicative content, for example, a comment on a Commit or a direct message within the document, that comment was placed in the classification column, otherwise the action was placed in the column within square brackets. Because Issues, Pull Requests and comments always had communicative content, and frequently long and sometimes rich media content, a short description of the content similar to Table 11 was used and placed in the relevant column/s, using the verbs at Table 12. If there was no comment with the issue or PR, there is no comment in either the epistemic/regulative columns or the social presence column. For example, where at comment 1018 C3 says “Yeap, I checked and it's all good! Now, we have to check the content as [C6] requested it. I'll take a look at it today and come back to you later!”, the communication is described as “confirm current status and location of use case, confirm will provide feedback as planned”, and classified as regulative with High relational presence because it includes positive aspects of immediacy/affection, similarity/depth, and dominance/control. It’s direct, personal and informative.

Table 12: Examples of verbs that are used to describe the communicative action or interaction..

Verb	Example
Agree	"I agree, yes I think"
Confirm	"Yes that's right"
Support	"Sounds like a good idea"
Approve	"I approve, go ahead" (when confirming change to document)
Clarify	"It works like this"
Suggest	"I've had a go"
Notify	"I've updated"
Approval comment	"Approved!" (when confirming merge to master)
Acknowledge	"no worries" is the whole text of the comment

Team C's data required some manual adjustments to the analysis method, as the way they had used the GitHub environment had created data types not captured in the data export. This is one of the considerations when using GitHub for research dealt with further in the Discussion chapter.

A specific property of the GitHub environment is the transparency around workflow and editing, and this necessitated the addition of another classification to the dataset during the analysis process. The 'tidying' classification was created for actions that are minor edits on documents that relate to document formatting and production. An example from the tidying category is Commit 4795cbd, where A1 removed the guide text which had been provided in the template and modified the headings for consistency in language and formatting, an activity that does not sit entirely within either the epistemic or regulative categories, and which is also considered in the Discussion chapter.

4.7.1.4. Reviewing themes

The two levels of review appropriate in thematic analysis are to review the coding to consider whether coherent patterns can be identified, and, if so, to re-read the data set to ascertain the relevance of the themes in relation to the whole, and to identify missed data now the coding conventions have been established (Braun & Clarke, 2006).

Once the data had been coded at individual interaction level, each classification was reviewed as a set to establish whether the coding was consistent in the way it had been applied in relation to the epistemic, regulative and other classifications (Damşa, 2014; Damşa et al., 2010; Damşa & Ludvigsen, 2016), first within each team's data, then across all the cohort's data. The coding of the emergent classifications 'relational presence' and 'tidying' was reviewed for each group, and the cohort as a whole, and instances which were borderline were categorised.

For example, Commit cb6e61b9 “The following two links provide an insight on how the perceived automated learning management system supports the continuous improvement of not only courses and learning material but learning designs that have been developed by multiple sources.” was reclassified to *epistemic-4-revising object drafts*, because while it doesn’t say much, it does make a contribution to the content of the document. In contrast, Commit 7725942 “The weekly diagram provides a more detailed description of the responsibilities for each team member as well as a breakdown of the agreed weekly timeline for meetings, contributions and feedback.” above a link was retained as ‘tidying’ because it contained no information and was essentially a heading rather than content.

Another borderline issue was when actions were specifically to use a system feature, for example, changing the Markdown so that well-formed checkboxes displayed. These remained categorised as ‘tidying’ rather than either epistemic or regulative to balance the absence of a contrasting code for where actions mis-appropriated system features, or where system features could have been used but were not. These can be seen as examples of ‘good tidying’, individually agentic behaviour improving the overall quality of the group’s work. In contrast, individually agentic behaviour reducing the overall quality of the group’s work are examples of ‘bad tidying’.

The alignment of interactions and actions in GitHub with the coding schema used in Damşa (2014); Damşa et al. (2010); Damşa and Ludvigsen (2016), the ‘other’ category added in Damşa & Ludvigsen, (2016), and the emergent classification ‘tidying’ is at Table 13.

Table 13: General alignment of GitHub actions with (Damşa et al., 2010) and Damşa & Ludvigsen (2016) schema.

Coding categories	Associated asynchronous actions in GitHub
1) Creating awareness Identifying/defining problem Identifying lack of knowledge	note where knowledge is incomplete (contrast to work that is incomplete)
2) Alleviating lack of knowledge Examining given sources Collecting additional information Sharing information (from sources) Structuring new concepts/knowledge	add an initial narrative, diagram or code add reading summary ask for help with task problem suggest diagram, narrative or code
3) Creating shared understanding Creating explanations for concepts Problematizing (Re)framing problem/focus Discussing misunderstandings	ask for feedback or critique clarify principle or component express confusion about model elements express new understanding suggest solution or workaround
4) Generative collaborative actions Generating new ideas Idea uptake Negotiating new ideas Elaborating concepts/ideas Revising object drafts Providing and using feedback	add a narrative to an existing diagram or code add document from template edit narrative, diagram or code provide feedback support suggested diagram, model or code
5) Projective Setting common goals Joint planning Coordinating process	add a reference to the GitHub location relevant to the task or goal add or edit note who is to do task add or edit meeting agenda note a task needs to be done suggest workflow
6) Regulative Monitoring process Evaluating progress and outcomes Reflecting on and adjusting strategy	add intro and link to other location in repo add meeting recording URL add or edit note where task is incomplete (contrast with knowledge that is incomplete), has been completed or needs revision confirm following plan edit meeting notes to record attendance edit meeting notes to record duration express confusion about task requirements support workflow
7) Relational Facilitating others' contributions Transcending conflict	empathise thank
8) Other Unrelated, social chat	
9) Tidying *(new category)*	add backticks to bracket code add/edit heading add/remove blank line/s change heading number, level, or format create/delete dummy file/folder delete annotations in text delete unnecessary/redundant file/folder edit meeting recording URL edit to create proper checkboxes edit to remove guide text minor text editing, for example, changing one word partial edit, for example, adding a number or dot point without adding the associated text rename for consistency punctuation, grammar or formatting changes

4.7.1.5. Defining and naming themes

After a satisfactory map of the data was created, the next stage was to further refine the themes presented for analysis, and then to organise the data extracts into a coherent account with accompanying narrative (Braun & Clarke, 2006). Descriptive quantitative data was included for the classification of interactions and actions.

To refine the analysis and construct the narrative, individual and joint interactions and actions of the participants were reviewed and a series of conjectures constructed describing the main aspects of their collaboration within the different dimensions of agency in the classification framework. To ensure consistency across the groups and a strong relationship with the coding schema, the conjectures were informed by the descriptions of observed behaviours used by (Damşa et al., 2010).

4.7.1.6. Producing the report

As part of the report preparation process, a secondary analysis was conducted on each team's self-reported meeting notes and process documentation to triangulate the findings. The results from the secondary analysis were used to evaluate whether the conjectures from the asynchronous data were supported, partially supported or not supported. This improves the credibility of the findings in the absence of other validation mechanisms such as a secondary coder. Section 5.9 discusses the results of that evaluation.

4.7.2. Synchronous meeting notes and process documents

The procedure again generally followed the six phases of thematic analysis established by (Braun & Clarke, 2006), and to avoid repetition the phases are not delineated here by headings.

Each team's meeting notes and process documents were identified within their repo, then converted to PDF, uploaded to the university's Research Data Store and a copy made on the researcher's local computer for coding and analysis. This resulted in the final set of synchronous meeting and process documents for secondary analysis summarised at Table 14.

Table 14: Breakdown of meeting notes and process documents for analysis by team.

Meeting & Process Documents by Team	A	B	C	Total
contributing.md	1	1	1	3
Insights.md	1	1	1	3
Processes.md	1	1	1	3
Roster.md	1	1	1	3
Admin and process documents	4	4	4	12
Meeting Notes	7	6	7	20
Total Documents	11	10	11	32

The MAXQDA2020 Qualitative Data Analysis software (MAX) application (VERBI Software, 2018) was used for this stage of analysis.

4.7.2.1. Meeting notes

Each file was imported to MAX, and each section of the contents highlighted and a specific code applied to the highlighted area reflecting the classification of the activity.

To get as close a match to the analytical process that was used for the asynchronous data as possible, the classification scheme designed by Damşa et al (2010) was used, but was applied in a different way. Where the asynchronous data analysis was coded at interaction and message level, each set of synchronous meeting notes included multiple interactions, so the data coding was done at sentence level to reflect that. Figure 23 illustrates this with an excerpt from Team C's meeting notes, with specific elements from the document highlighted with a code indicating the classification that most closely reflects the activity.

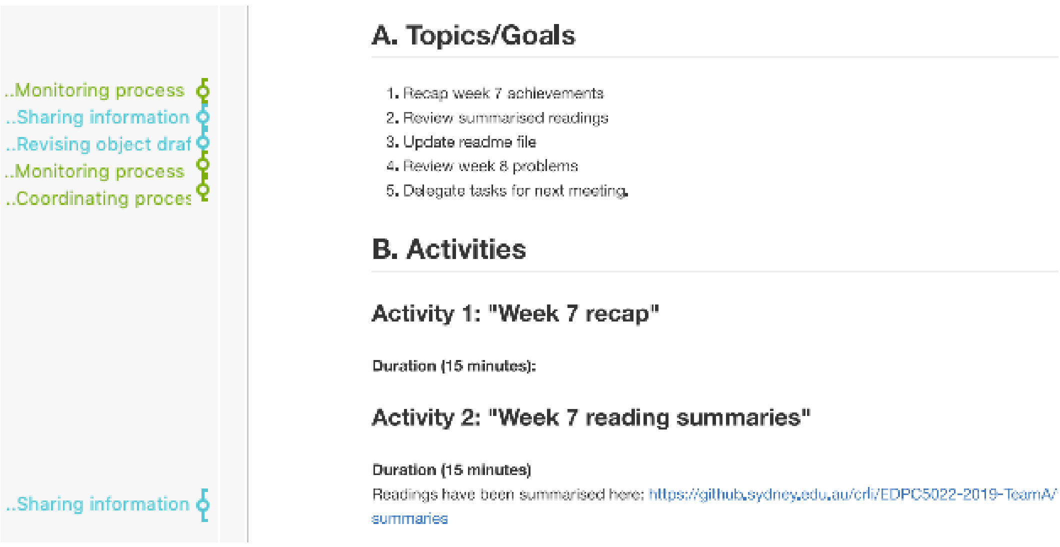


Figure 23: Partial screenshot from MAXQDA showing example of coding for meeting interactions using the same classification system that was applied to the GitHub asynchronous interaction data but at a different level of granularity.

As GitHub documents persist in the environment, meeting agendae were usually drafted and then subsequently modified to incorporate the meeting minutes in the same document. An example of this iterative process is shown at Figure 24. However, it is the final version of the notes which was subject to analysis.

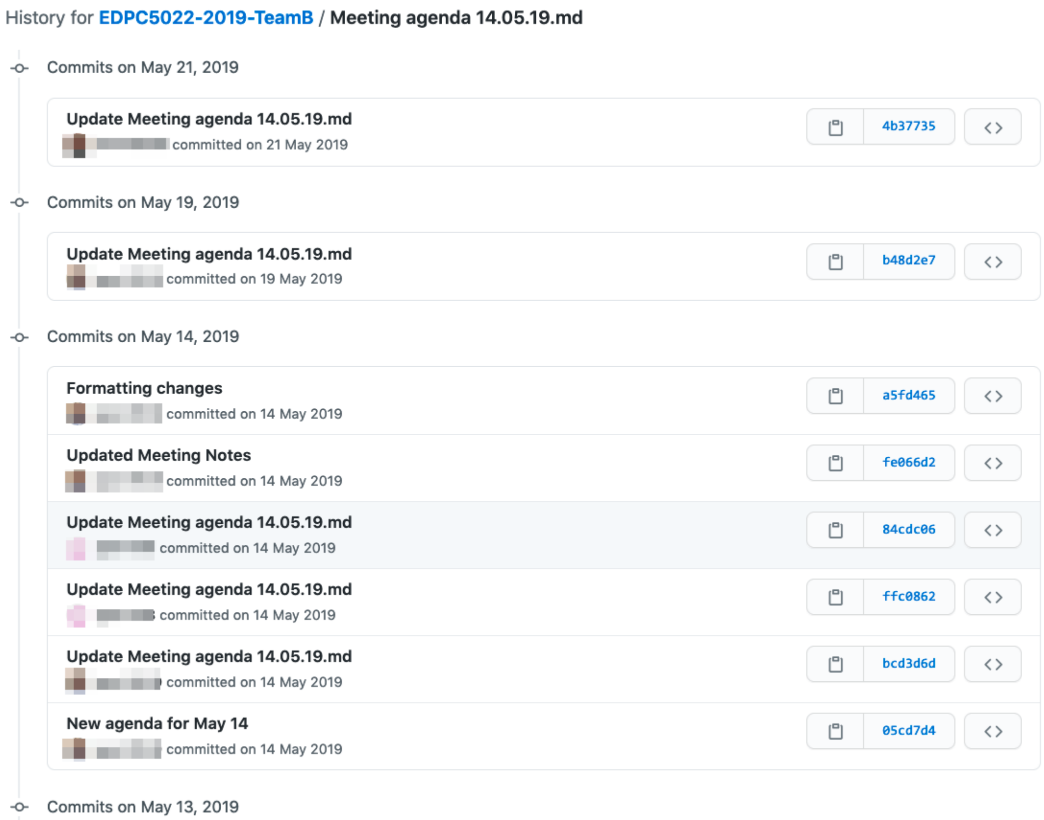


Figure 24: Document history of Team B's notes from their 14.05.19 meeting showing iterative development from an initial meeting agenda.

Methodological issues

A consideration when classifying the actions described in the meeting notes was that each document typically had a section at the beginning of the document which was present on the original template (Section A – see template in Appendix G), and which did not always reflect the following content of the notes. This section was also coded, and a note was made in the document where that topic or item was not present in the subsequent discussion.

Classification examples

An example from the epistemic category is "Discussion - Is the Wow Factor clear in our Summary? - Angela-Claire" (B-Meeting - 21.05.19, P. 2: 0), coded as 'Elaborating concepts/ideas'.

An example of the regulative category is "Review items currently in the repository, provide feedback and ensure consistancy with larger project vision." (A-Minutes 10-05-19, P. 1: 364), coded as 'Evaluating processes and outcomes'.

After the data had been initially coded, a review indicated that the epistemic, regulative and other dimensions were sufficient to classify the data, and that there were no emergent themes related to epistemic agency. The coding was then reviewed between groups to ensure consistent application of classification for similar items, for example, in the last set of notes from Teams B and C, the allocation of presentation topics to individual group members was in both cases coded as *regulative*. A brief summary of each meeting was then created, and a word cloud constructed representing the frequency of action categories for each team.

The results from this analysis were then considered with the review of the process documentation discussed at Section 4.7 and compared with the conjectures resulting from the analysis of the asynchronous data, with the results discussed at Section 5.9.

4.7.2.2. Process documentation

Each document was reviewed and the self-reported processes compared with the meeting notes to establish the level of consistency between the workflow models and contribution framework and the meeting notes. Together, these artefacts were compared with the conjectures resulting from the analysis of the asynchronous data. For example, the workflow model at Figure 25 below indicates the use of a structured knowledge object approval process, one of the characteristics of collaboration associated with the epistemic dimension of activity. If this is also evident in the meeting notes, together this supports a conjecture that the team used a structured approval process. In the absence of evidence in the meeting notes, it would partially support this conjecture as it indicates an intention but not necessarily an implementation.

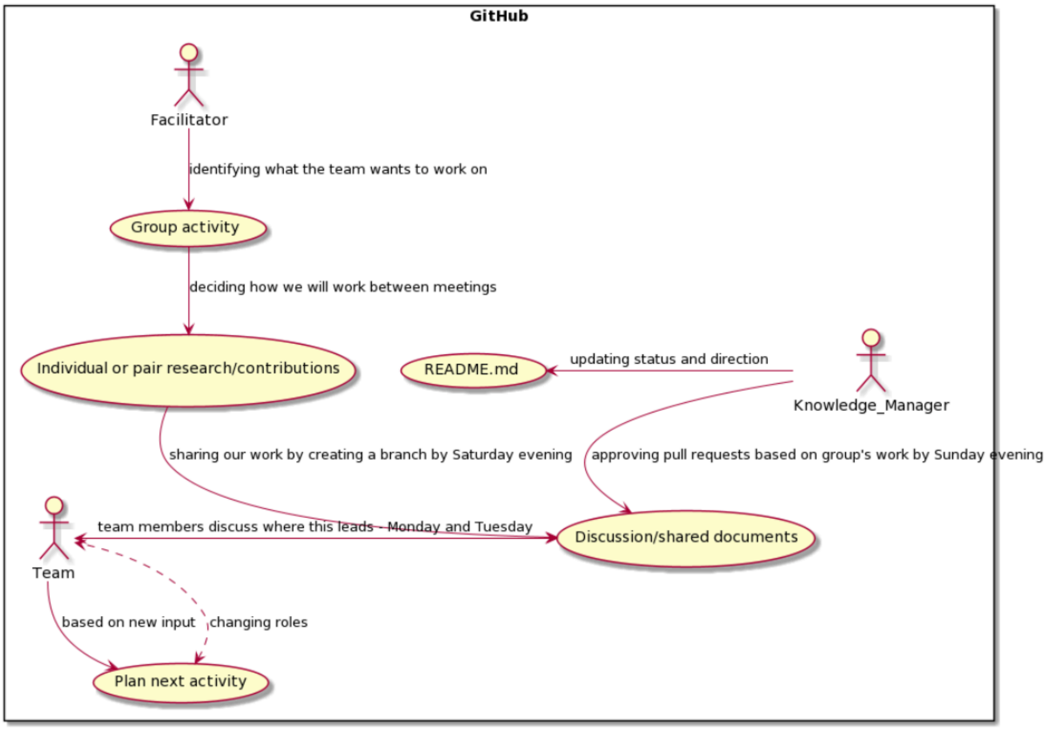


Figure 25: Partial screenshot showing example workflow model with Knowledge_Manager 'approving pull requests...' indicating a structured knowledge object approval process.

1.1.1. Summary of data analysis procedure for Stage 1

To answer the first research question, analysis was conducted in two stages. Stage 1 was most relevant to sub-question (a), and Stage 2 to sub-question (b). Asynchronous data was first coded at individual interaction and action level in categories within epistemic, regulative and other dimensions. The data was then reviewed at joint individual/group level and organised into themes describing characteristics of collaboration. A series of conjectures about each team's collaboration were then constructed.

As a validation mechanism, the contents of synchronous group meeting notes were then coded using the same classification scheme, and organised into themes using the same descriptors of characteristics of collaboration. These were compared with the conjectures to assess to what extent the conjectures could be supported with the addition of the meeting notes data.

As a secondary validation mechanism, the contents of group process documents were compared with the conjectures and the meeting notes analysis to assess to what extent the process data might be supported by the meeting notes, and subsequently to what extent the conjectures might be supported by the process data. The result is a set of descriptive statements about each team's characteristics of collaboration which are supported by the data and analysis. This analysis was followed by Stage 2.

4.8. Analysis procedure: Stage 2

To answer sub-question (b) of the research question, the GitHub interaction and actions relating to each document's construction were reviewed to identify trajectories of activity and productive interactions. From this, a series of conjectures about the indicators of shared epistemic agency within each team were then constructed based on sequences of sustained joint action resulting in concrete changes to a knowledge object.

4.8.1. Document construction processes

Each iteration of each of the team's *Use-cases.md*, *Components.md*, *Interactions.md* and *README.md* documents was accessed in the GitHub GUI, and the actions comprising its development reviewed. Productive interactions were defined as those (a) leading to a concrete advancement of the knowledge object (b) incorporating more than one team member's contribution. While Damşa (2014) used a timeframe of one week from interaction to advancement, as these students were part-time, adult and in some cases fully online, no time limit has been applied in defining interactions as productive which resulted in knowledge object advancement.

The goal of trajectory analysis is to identify new levels of organisation Lemke (2000), observed in our data by a change to a knowledge object that is done with the explicit input of two or more participants, indicating a shared approach to the transformation. This stage of analysis identified patterns comprising deliberate (Damşa et al., 2010) and regular (Damşa, 2014) actions involving the creation of awareness within the group of problems or a lack of knowledge, sharing ideas and alternatives for object development, and engagement in productive activities that result in advancement of their knowledge object/s.

Each change to each document was viewed, with concrete advancements considered to the addition or substantive change to a narrative, model or code in the direction of task completion. Substantive changes were those which were meaningful contributions, for example, adding a layer in the model or incorporating a new idea by modifying the way a model worked. Adding or modifying a heading was not defined as a substantive change, but adding academic references to a design critique was. While all substantive changes were classified as knowledge object advancement, there were other knowledge object advancements that were not classified as substantive changes, for example, adjusting the Markdown code to display a document inline correctly.

For each substantive change, Commits, Issues, Pull Requests and comments were searched for any mention of the document or topic. Where it was visible that input from more than one team member was included in the change, that interaction was considered a productive interaction and indicative of shared epistemic agency. Where input or feedback was provided and not incorporated in the group's knowledge objects, this was also noted. In many cases, there were equivalent Commit, Issue and Pull Request comments for the one change, in which case only the first instance was coded, resolving the problem identified earlier with duplication in the data. As the GitHub data did not associate interactions with documents, each interaction was associated manually with a document based on the Commit, Issue or Pull Request that occurred at the most proximate time if sufficient other information was not available to confirm its association. System-generated actions *closed*, *referenced*, *merged*, and *subscribed* and data generated by the instructors were ignored. As teams did not consistently use the features *assign* or *review_requested*, these were not considered in the trajectory analysis and limited to descriptive statistics.

After all remaining interactions had been coded as knowledge object advancement (KA), productive interaction (KP), or 'other', they were mapped by week to establish the level of each type of interaction over the course of the collaborative project for each knowledge object, each team and each participant. A narrative was constructed about the trajectory of the knowledge objects' construction, and a summary of observations related to productive interactions and indicators of shared epistemic agency reported for each team. Descriptive quantitative data was included for productive interactions and level of relational presence.

1.1.2. Summary of data analysis procedure for Stage 2

Stage 2 of analysis is most relevant to sub-question (b) of Research Question 1. The findings from Stage 1 were used in conjunction with a trajectory analysis of iterative changes to each knowledge object to locate indicators of epistemic agency and specifically productive joint actions. Productive actions over time were analysed by volume, frequency and connection to each knowledge object and a narrative constructed for each document's construction.

Productive interactions were also reported by level of relational presence. Observations about the emergence of shared epistemic agency for each team were summarised.

The results of these analyses are in the following chapter.

5. Results

This chapter answers the research questions by presenting qualitative findings about the way in which agency might be observed in the activities of each student and group, followed by quantitative findings about the frequency and distribution of actions within the whole cohort, each team, and individual participants that are classified as indicating epistemic agency, regulative agency, 'other' activity or are 'tidying'. Figure 26 below provides a quick overview of the organisation of this chapter.

Section 5.1:	Overview of the types of agency observed across the groups.	*Research Question 1(a)*
Sections 5.2-5.6	Indicators of agency observed in each team's GitHub data through epistemic and regulative activities; findings around relational presence; characterisation of collaborative behaviours.	
Sections 5.7-5.9	Secondary data analysis triangulation and re-evaluated observations.	
Section 5.10	Overview of trajectory representations	*Research Question 1(b)*
Sections 5.11-5.13	Trajectories of development observed for each knowledge object for each team.	
Discussion		*Research Question 2*

Figure 26: Organisation of the Results chapter.

The chapter then reports the results from the two stages of analysis addressing the first research question about the observation of agency at individual and group level. Stage 1 is a thematic analysis of actions and interactions in the GitHub collaborative environment, using a classification framework of actions in epistemic, regulative and 'other' dimensions to categorise activity at individual and group level, to identify manifestations of agency at individual and collective levels. These results are used to construct a series of conjectures about the types of agency that can be observed in each group. A secondary analysis of process documents using the same framework is used to triangulate the findings, and establish to what level the conjectures based only on GitHub data can be supported. Stage 2 is a trajectory analysis of how these actions and interactions are associated with iterative changes to the group's documents over time, to identify productive actions involving multiple participants leading to knowledge object advancement, indicating manifestations of shared epistemic agency. Together, these findings answer both parts of the first research question and through the methodological description in Sections 4.1-4.8 (and Appendix F for the more technical details) and further consideration in the Discussion chapter answer the second research question.

The actions included in this data are GitHub Issues, Pull Requests, all comment types, and Commits related to the assessable documents. Three knowledge objects comprised the group modelling task: *Use-cases.md*, *Components.md* and *Interactions.md*, each containing a different system view. Each team was also asked to keep a *README.md* file in their repo, updated with the current 'state of play', that is, what the repo contains and what the visitor should expect to find within it. Descriptions of these knowledge objects are at Table 15.

Table 15: Purpose of the knowledge objects which were specified in the group project task description.

Knowledge Object	Description
Use-cases.md	Models and narratives that are used to gather the requirements of a system including internal and external influences, including actors that use the system functions.
Components.md	Models and narrative describing a high-level overview of the elements that make up a system.
Interactions.md	Sequence, activity and interaction models and narrative describing the dynamics of a system over time: how users and components interact.
README.md	Current state of play of the repo.
Custom	All teams developed intermediate knowledge objects that were not part of the task scope.

Each team also co-constructed collaborative process models and a narrative around their collaboration as well as taking meeting notes. Descriptions of these documents are at Table 16.

Table 16: Process documentation which were not specified in the group project task description.

Knowledge Object	Description
Contributing.md	A narrative description of team processes to scaffold negotiation and participation.
Processes.md	A model of team processes to scaffold negotiation and participation as well as PlantUML skills.
Insights.md	An unstructured document to scaffold reflection and contribute to the individual reflection task.
Meeting Notes	Records of aims, processes and outcomes of team meetings to scaffold participation and decision-making.

Section 5.2 provides an overview of cohort activity by group, participant, team member and broad classification.

Section 5.3 presents the results of analysis Stage 1 for Team A, 5.4 for Team B, and 5.5 for Team C. Section 5.6 sets out a series of conjectures about each team's collaborative processes in relation to the different types of agency. Section 5.7 presents the results of the analysis of process documentation. Section 5.8 compares the results of Sections 5.6 and 5.7. Section 5.9 sets out the resulting revised set of conjectures.

Section 5.10 presents an overview of the results of Analysis Stage 2, followed by 5.11 detailing the findings for Team A, 5.12 for Team B, and 5.13 for Team C.

To enhance readability, limited illustrative extracts are included below, and unique identifiers for interactions have not been included in the narrative. A wider selection of examples is available at Appendix H.

5.1. Overview

5.1.1. Individual and collective agency

Actions indicating epistemic and regulative dimensions of agency are visible at individual and group level from qualitative and quantitative analysis of comments, Commits, Issues, Pull Requests and other interaction traces such as approval, pull request and review comments. This analysis led to broad conjectures around the way each team works, which in most cases can be supported by analysis of self-reported team meeting notes and process documents. As well as frequency and type of contributions, this analysis also reveals the impact each contribution has on the overall project, and the way in which decisions are made about what is included in the final knowledge objects for submission. We can see iterative development at knowledge object level, showing the number and nature of advancements.

Team A's collaboration was characterised by contributions which, overall, were fairly evenly divided between epistemic and regulative actions. The majority of epistemic actions related to sharing information from sources and individually adding to object drafts. Almost two-thirds of actions by Team A were Commits, with around a quarter then comments and less than ten percent Issues and a Pull Request. Team B had slightly more actions overall – and a team of six compared to Team A's four – and a larger proportion of epistemic actions, with nearly twice as many as regulative. While the majority of their epistemic actions were also individually adding to knowledge object drafts, they also engaged in epistemic activity around identifying and addressing their lack of knowledge, and reframing or discussing misunderstandings. Team B's

Commit actions comprised just under half their total activity, with almost the same proportion of comments of various types, and the remaining activity being Issues and a Pull Request. In both Teams A and B the number and type of contributions was variable across team members. Team C had almost as many actions as A and B combined, with substantially more epistemic than regulative activity, and a similar spread across the epistemic categories to Team B. Team C was also similar to Team B in the breakdown of interaction types, with just under half their actions being comments, followed by a slightly smaller proportion of Commits, and the remainder of actions being Issues, Pull Requests and review comments.

Within the classification structure, predominant aspects of the collaborative process could be identified in the data for each team. These related to identification of needs and goals, the collection and use of additional information, discussions around knowledge object development, efforts to understand the principles, tools and task, approaches to feedback and workflow, engagement in shared monitoring of knowledge object development and quality, and the interpersonal characteristics of team member interactions. When these were analysed in conjunction with the team's self-reported meeting notes, these were generally supported, indicating that in many cases analysis of the GitHub asynchronous data alone may be sufficient to establish a general picture of the collaborative characteristics of each team and the specific areas in which agency is manifested.

5.1.2. Shared epistemic agency

Indicators of shared epistemic agency are visible at individual and group level from qualitative and quantitative analysis of knowledge objects in connection with comments, Commits, Issues, Pull Requests and other interaction traces such as approval, pull request and review comments. It is possible to identify productive interactions resulting in knowledge object advancement, and to observe when these interactions are sustained over time, where they are sustained by multiple team members, and which knowledge object/s they occur in relation to.

Team A's agency was visible through productive interactions resulting in changes to their knowledge objects. These interactions were considered 'interactions' as they involved more than one team member, but tended to be a single team member asking or instructing another to perform an object-oriented task. In two instances, team members contributed new intermediate knowledge objects without prompting, and one of these was used by others to some extent. There was little evidence of sustained activity in relation to each knowledge object, with the team having a strong task division approach and no visible feedback process. The collaboration had a high proportion of interactions that were unproductive and did not advance the knowledge objects past initial individual development. The few comments on GitHub Commits give little information about the team's goals or uptake of ideas from members. The actions indicating epistemic agency were predominantly related to knowledge object advancement.

Team B demonstrated agency through productive interactions in relation to their knowledge objects, particularly *Use-cases.md* and *README.md*. While models tended to be constructed by individuals, there was evidence of epistemic agency in continued development and explanations of the rationale for changes in Commit comments. Interactions between team members included asking questions about the knowledge objects or ideas presented, and these were sometimes responded to but rarely resulted in advancement. There was sustained discussion around the *README.md* that included the sharing of theoretical as well as personal perspectives. Activity across the team increases from Week 9 until the task submission date, with the most productive interactions in the final two weeks, but, overall, object-oriented activity is more focused on knowledge object advancement than interaction. Actions indicating epistemic agency were predominantly unproductive in that they did not lead to knowledge object advancement. Agency is also indicated in destructive actions by individuals such as the changes made during 'bad tidying'.

Team C engaged in frequent and sustained productive interactions over the course of the project as well as in constant knowledge object advancement. Feedback was frequently sought and provided at all levels from conceptual to technical, sometimes including example models or code to illustrate their thinking. New ideas were introduced and their rationale described to the team using Issues or Pull Requests. Team members discussed the relationship between the discrete knowledge objects and all worked to ensure their alignment when a major change was made to what they had agreed was the 'parent' model. Actions indicating epistemic agency were evenly divided between productive interactions, knowledge object advancement, and those actions which were neither productive nor advancement.

The following sections deal with the findings in more detail. For further excerpts illustrating data classification, see Appendix H.

5.2. Thematic analysis of GitHub actions and interactions

A summary of actions and interactions by team, participant and classification is at Table 17. This shows the number and type of interactions for every team member summarised by team and dimension. This highlights the differences between teams in the number and nature of contributions made by each team. To preserve participant anonymity, each team has been assigned a letter prefix from A-C, and within these, each participant has been assigned a random number. In the following tables and graphs, ‘A1’ to ‘A4’ indicate the four participants in Team A, ‘B1’ to ‘B6’ those in Team B, and ‘C1’ to ‘C6’ those in Team C.

Table 17: All epistemic, regulative, relational and tidying actions and interactions for all teams by team, team member and classification.

	⊟ Epistemic				Epistemic Total	⊟ Regulative			Regulative Total	⊟ Tidying	Tidying Total	Grand Total
Team and Participant	Creating awareness	Alleviating lack of knowledge	Creating shared understanding	Generative collaborative actions		Projective	Regulative	Relational		Tidying		
⊟ A	7	45	9	52	113	53	46	6	105	87	87	305
A1	3	8	3	10	24	15	20	2	37	45	45	106
A2	1	13	6	17	37	27	8	2	37	21	21	95
A3	2	14		8	24	2	12		14	3	3	41
A4	1	10		17	28	9	6	2	17	18	18	63
⊟ B	15	29	16	115	175	27	59	6	92	79	79	346
B1	5	4	4	26	39	4	7	4	15	20	20	74
B2	2	9	4	28	43	1	10		11	25	25	79
B3	2	1	2	16	21	1	11	2	14	1	1	36
B4	5	7	4	29	45	12	26		38	14	14	97
B5	1	6	2	9	18	3	4		7	7	7	32
B6		2		7	9	6	1		7	12	12	28
⊟ C	26	46	57	153	282	40	140	16	196	126	126	604
C1	7	11	9	26	53	12	14	2	28	17	17	98
C2	3	9	8	26	46	4	22		26	9	9	81
C3	4	15	23	31	73	7	45	6	58	26	26	157
C4	2		2	18	22	7	17		24	44	44	90
C5	1	4	2	20	27	4	16		20	10	10	57
C6	9	7	13	32	61	6	26	8	40	20	20	121
Grand Total	48	120	82	320	570	120	245	28	393	292	292	1255

A summary of actions and interactions by team, participant and relational presence is at Figure 27. This shows the number of interactions at every level of RP for every team member summarised by team. This highlights the differences between teams in the volume and proportion of activity at different levels of relational presence.

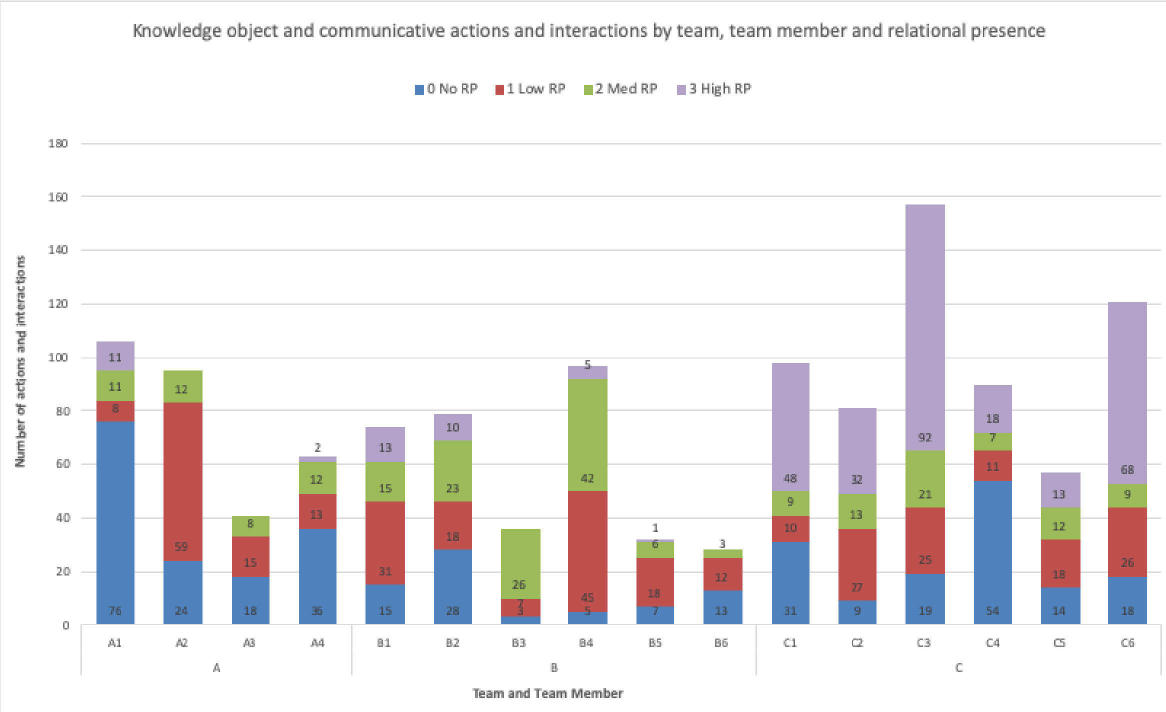


Figure 27: All epistemic, regulative, relational and tidying actions and interactions for all teams by team, team member and relational presence.

Interactions are reported here which relate to knowledge objects or contain communicative content. System-generated events such as *closed* and Pull Requests that duplicate Issues are not included. As teams used different features of the environment, not all teams have the same interaction types, and as teams worked differently together, not all teams have data about the same categories of activity. The data is divided into epistemic (knowledge-related), regulative (process-related), and other dimensions of collaborative activity, and 'tidying' actions, and then sub-categories across epistemic and regulative dimensions.

Type of actions that are associated with each sub-category are below at Table 18 and a full list of actions and associated GitHub actions is at Section 4.7.1.4. The 'other' category is used for purely social interactions, and 'tidying' for minor document edits that do not advance the knowledge object. They have been omitted in this Table to enhance readability.

Table 18: Examples of actions within each classification (Damşa et al., 2010).

Epistemic dimension				Regulative dimension		
1) Creating awareness	*2) Alleviating lack of knowledge*	*3) Creating shared understanding*	*4) Generative collaborative actions*	*5) Projective*	*6) Regulative*	*7) Relational*
Identifying/ defining problem	Examining given sources	Creating explanations for concepts	Generating new ideas	Setting common goals	Monitoring process	Facilitating others' contributions
Identifying lack of knowledge	Collecting additional information	Problematizing	Idea uptake	Joint planning	Evaluating progress and outcomes	Transcending conflict
	Sharing information (from sources)	(Re)framing problem/focus	Negotiating new ideas	Coordinating process	Reflecting on and adjusting strategy	
	Structuring new concepts/ knowledge	Discussing misunderstandings	Elaborating concepts/ ideas			
			Revising object drafts			
			Providing and using feedback			

5.3. Classification of GitHub actions/interactions: Team A

A breakdown of knowledge object and communicative actions and interactions in each dimension and category for Team A is at Table 19.

Table 19: Team A Comments, Commits, Issues and Pull Requests by team member and classification.

	⊟ Epistemic				Epistemic Total	⊟ Regulative			Regulative Total	⊞ Tidying	Grand Total
Team Member and GH action	Creating awareness	Alleviating lack of knowledge	Creating shared understanding	Generative collaborative actions		Projective	Regulative	Relational			
⊟ A1	3	8	3	10	24	15	20	2	37	45	106
Comment	1		3	1	5	5	6	1	12		17
Commit	2	8		8	18	5	11	1	17	45	80
Issue				1	1	5	3		8		9
⊟ A2	1	13	6	17	37	27	8	2	37	21	95
Comment	1	1	4	2	8	11	5	2	18		26
Commit		9	1	14	24	13	1		14	21	59
Issue		3	1	1	5	3	2		5		10
⊟ A3	2	14		8	24	2	12		14	3	41
Comment	1	4		3	8	2	11		13		21
Commit	1	6		5	12		1		1	3	16
Issue		3			3						3
Pull R		1			1						1
⊟ A4	1	10		17	28	9	6	2	17	18	63
Comment	1	1		5	7	4	6	2	12		19
Commit		8		11	19	2			2	18	39
Issue		1		1	2	3			3		5
Grand Total	7	45	9	52	113	53	46	6	105	87	305

5.3.1. Epistemic dimension of actions

5.3.1.1. Creating awareness

Clarify goals

Team A focused on task completion, and the needs identified relating to the regulative organisation of the epistemic work. The GitHub interaction data does not reveal conversations about what the team members thought about the narratives, diagrams and code that were being developed, or the underpinning theory or practice considerations that were their foundation. Discussions creating shared understanding are not visible, nor are evaluations of multiple ideas or decisions about preferable approaches.

5.3.1.2. Alleviating lack of knowledge

Gather relevant additional information

Team A sought additional information and added three summaries of readings individually early in the project. However, we can’t see how they are used in the construction of the knowledge objects as they are not the subject of further GitHub actions.

Structure and organise knowledge

There was an occasion where a team member went toward engaging the entire group in gaining deeper theoretical understanding, providing a structured template for the conduct of a Design Critique in response to the instructor-initiated task. The model comprises a narrative, diagram and code suitable for a system implementation but without academic foundation for the critique process. The two team members providing their critique after the template link was posted followed most of the steps in the narrative section.

5.3.1.3. Creating shared understanding

Share insights

Team members shared resources, for example the URLs of use case diagram examples, and some paragraphs on learning design tools. However, the links to the use case diagrams are simply introduced by "check out these links for examples of use case diagrams", and the diagrams themselves are simply drawings without the associated code.

Other than these URLs, there are no mentions of using sources, scaffolding materials, resources or other bodies of knowledge in relation to using the GitHub environment, Markdown or UML modelling despite those being available within their repo, at university level, and in rich variations on the internet.

5.3.1.4. General collaborative actions:

Prepare the report collaboratively

Team A generally approached the collaboration through task division, at a first level in the documents themselves, where on occasions they noted where work was outstanding by noting the assigned team member in the relevant document. Each model was added to the appropriate shared documents one at a time by the individual team member who had been assigned it, and additional work was delegated ad hoc when two team members did not continue with the project, or when required. At a second level, it is observable in messages between team members where tasks are incomplete.

Develop a systematic feedback process

The data does not provide much insight into a strategy around asking for feedback, more a practice where knowledge objects or collaborative processes were provided as conclusive and discussion was not necessary. However, there were two exceptions early in the collaboration where feedback was provided on others' work, both relating to document merge and location processes.

After a narrative, diagram or code had been Committed to a document, it was rarely altered except to address technical errors in display or editing. For example, as part of the instructor-initiated Design Critique of Team A's *Interactions.md* model, two team members identified the unlimited data storage timeframe as a design limitation and suggested the addition of a reduced storage period. This change was not made, nor were any other recommended modifications.

Prepare report collaboratively

The GitHub data shows that Team A's knowledge objects were broken into components which were then drafted individually, with team members labelling their contributions with their name, sometimes as a discrete edit after the work has been done. Names were removed before the team presentation and task submission. Around a quarter of Team A's edits were in the last two weeks of the project and were in the 'tidying' category.

There were occasions where a team member's contribution was done only partially, was not provided, or was provided to a lower standard because of a lack of understanding which had not been addressed through searching for information or asking others. For example, two team members expressed lack of knowledge around constructing UML diagrams they do not mention any problem-solving strategies such as searching the repo or online resources.

We do not see discussion around knowledge objects once they have been Committed, with the completion of contribution considered finalisation without a further review of content or quality except for 'tidying' and technical editing prior to task submission. These also tended to be done unilaterally, for example, A4 changes a heading that A1 deletes in its entirety an hour later. The timing of this Commit does not coincide with the synchronous meeting time, so it is likely this change was made without consultation, although it is possible, as discussed in Limitations, that there were additional backchannels used by team members to communicate outside the GitHub environment.

It was not clear that knowledge object quality, or the shared epistemic development of the team, were goals for Team A, for example, this excerpt from a comment indicates that once a diagram has been added to the correct document, further analysis is not required: "Added Use Case Diagram … Added a use case diagram that should meet the task requirements. ***…***Can someone compile a narrative (this just needs to be a description of the diagram with an academic spin).***…***I'll add some notes for the diagram in the issues tab."

5.3.2. Regulative dimension of actions

5.3.2.1. Projective

Agree on collaborative strategies

The GitHub asynchronous data did not provide insight into whether a specific agreement on a collaborative strategy had been reached. However, the document creation and interaction processes which could be observed in the data did not indicate a deliberate research, discussion and decision-making strategy. The proportion of all GitHub actions and interactions that had no communicative content at all for Team A was more than half, with the environment being used primarily for document co-construction.

We can see efforts to find information from each other about the shared space and about the task which continued throughout the team project, but we can't see examples of discussing their approach to the project or their approach to making decisions about how to work together.

Develop a structured knowledge object approval process

Early in the project we see examples of shared decision making on document construction , however, this method was not sustained for the duration of the collaboration.

5.3.2.2. Regulative

Monitor object development and quality.

When preparing their task for submission, the team interactions show a shared effort to finalise the knowledge objects in the sense of completing their 'assigned' part but not reviewing them as a collective or coherent set.

The GitHub data does not make the process for monitoring work in development clear, although there are interactions that indicate while it was not transparent or systematic it did occur. However, the interaction data does not support a shared monitoring of the state of the design product, for example, the response "Hey [A1]***……***I've knocked over my assigned task and updated my interaction diagram to include actions along the timeline of each object.***……***I'm not sure where the others are at seeing everything was due the other week.".

When additional work was required, the interactions around it are ad hoc, with a general call in an Issue for a volunteer to complete the task alone the way of managing the collaboration, using indirect language rather than asking a specific team member.

5.3.2.3. Relational

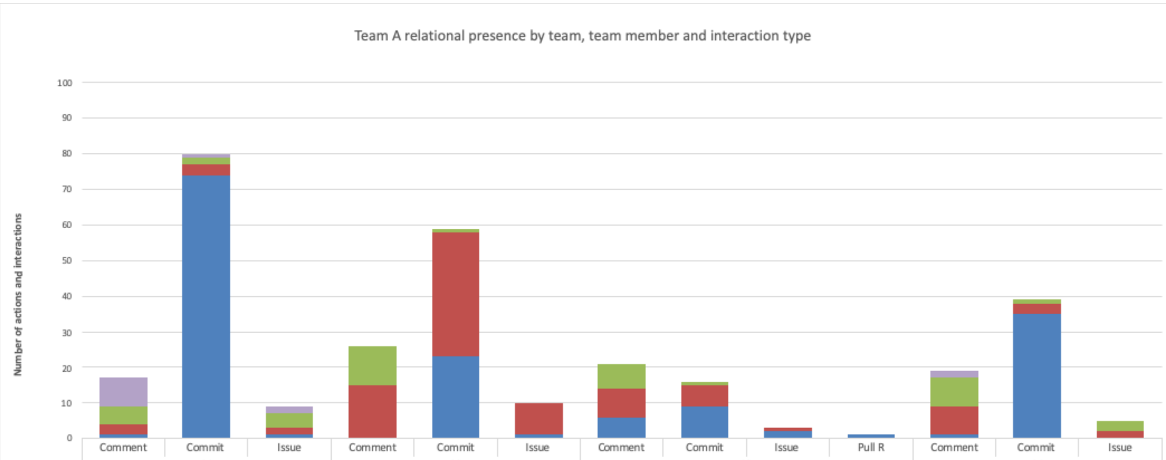
The relational comments in Team A's GitHub data were to provide a telephone number for contact, thanks for contributions and an apology for overlooking the location of a document.

5.3.3. Other dimensions

There was no social chat in Team A's interactions.

5.3.4. Emergent theme: relational presence

Team A spent little time on communicating in GitHub interactions, with more than half their Commits, Issues and comments having no content other than the default text, and their way of working included many Commits directly to the master branch by the person who created the model or diagram. Where there were interpersonal communications in GitHub their relational tone was impersonal and focused on task completion, and even when it was relational, lacked the warmth and personal features of other groups. Relational presence was not distributed evenly between team members, and while these figures can be seen only as indicative because of differing use of GitHub workflow processes between teams, a rough breakdown is shown at Figure 28, with some examples at Table 20 below. It's important to note that 103 Commits were of the 'tidying' classification, and A1 performed 47 of those, and while there's no reason they should not have a proper Commit comment, there is probably a strong temptation to see it as unnecessary. Two people from Team A (of six, then five, then four) added profile photos to the repo.



	A1 Comment	A1 Commit	A1 Issue	A2 Comment	A2 Commit	A2 Issue	A3 Comment	A3 Commit	A3 Issue	A3 Pull R	A4 Comment	A4 Commit	A4 Issue
3 High RP	8	1	2								2		
2 Med RP	5	2	4	11	1		7	1			8	1	3
1 Low RP	3	3	2	15	35	9	8	6	1		8	3	2
0 No RP	1	74	1		23	1	6	9	2	1	1	35	

Figure 28: Team A relational presence in Commit, Issue and comment interactions by team member.

Table 20: Examples of Team A's interactions at high, medium and low relational presence (RP) levels.

Reference	RP	Comment
1256	High	Hey [A4], can you post the UML you have along with your drawing? We can take a look tonight and probably find a little typo somewhere that will fix it =)
1646	Med	Hi @[A2] - I had a look and the issue was the @[A3] hadn't updated the PlantText URL, I ran her code through and it populated a different diagram. I've swapped it out so hopefully this is resolved?
1628	Low	Guys …I don't know what has occurred in the component.md page but it looks like [A3] has duplicated her component diagram. Can you please take a look and rectify the issue ASAP.

5.3.5. Team A's collaboration

When Team A did share ideas around theory, there was not an expressed intention to engage in discussion around them or to hear other perspectives. For example, when A2 adds excerpts from a paper prepared for another course, they simply notify the others they have added the information, and suggest they review the links they have included.

The GitHub data shows that all team members did contribute to the collaborative process and most to the shared knowledge objects to some extent. However, the quantitative data does not show the different ways in which team members contributed, for example, while A3's epistemic contributions appear almost as numerous as others, they include five repeated attempts to add the same use case diagrams and three comments repeating the same design critique, and A4's contributions include five trial and error attempts to resolve code issues in *Components.md*.

However, the data did not indicate that all team members contributed equally to decision making processes, or that they consciously monitored the quality of their knowledge object development. For example, as mentioned above, the feedback generated through the design critique process was not incorporated into the knowledge objects.

The data does not reveal collaborative knowledge co-construction, for example, one team member provides diagrams and some context but asks for someone (individual) else to "create narrative" around them. Had the models been created in a collaborative way, we could expect the narrative to emerge before or concurrently with the model[10].

[10] Something interesting about that particular model is that the nodes accessed by the discrete roles do not connect.

That comment points to a deeper issue in the way this group is working together on the task. If we take as being acceptable at face value a non-negotiated model whose function is solely to meet the task requirements, it is nonetheless problematic that the narrative is seen as a “description of the diagram with an academic spin”. We might expect that the narrative can both justify and explain the model not only in isolation but in connection with other models that the group are creating, and that instead of ‘academic spin’ there is an understanding of the benefits and limitations that have been considered in the model construction. The GitHub data does not reveal those considerations, but points instead to their absence.

5.3.6. Team A’s agency

Table 21 shows that Team A demonstrated agency predominantly in the regulative dimension, although epistemic agency was also observable in the progress of knowledge advancement. The majority of communication in GitHub was in the regulative dimension, whereas epistemic activity was weighted toward productional work on the knowledge object. Agentic behaviours were not evenly distributed across the team in any category. Relational presence was most frequently at no or low levels, with high levels most often associated with a single team member.

Table 21: GitHub interaction type for Team A’s comments, Commits, and Issues /Pull Requests that are epistemic, regulative, or tidying for all team members by classification. relational presence and team member.

	Team Member and activity classification															
	⊟ Epistemic				Epistemic Total	⊟ Regulative				Regulative Total	⊟ Tidying				Tidying Total	Grand Total
Activity type and relational presence	A1	A2	A3	A4		A1	A2	A3	A4		A1	A2	A3	A4		
⊟ Comment	5	8	8	7	28	12	18	13	12	55						83
0 No RP			6	1	7	1				1						8
1 Low RP		4		2	6	3	11	8	6	28						34
2 Med RP	1	4	2	3	10	4	7	5	5	21						31
3 High RP	4			1	5	4			1	5						10
⊟ Commit	18	24	12	19	73	17	14	1	2	34	45	21	3	18	87	194
0 No RP	16	5	6	17	44	13	9		2	24	45	9	3	16	73	141
1 Low RP		19	5	1	25	3	4	1		8		12		2	14	47
2 Med RP	1		1	1	3	1	1			2						5
3 High RP	1				1											1
⊟ Issue	1	5	3	2	11	8	5		3	16						27
0 No RP		1	2		3	1				1						4
1 Low RP		4	1	1	6	2	5		1	8						14
2 Med RP	1			1	2	3			2	5						7
3 High RP						2				2						2
⊟ Pull R			1		1											1
0 No RP			1		1											1
Grand Total	24	37	24	28	113	37	37	14	17	105	45	21	3	18	87	305

5.4. Classification of GitHub actions/interactions: Team B

A breakdown of knowledge object and communicative actions and interactions in each dimension and category for Team B is at Table 22.

Table 22: Team B comments, Commits, Issues, Pull Requests; approval, pull request and review comments, by team member and classification.

	Epistemic				Epistemic Total	Regulative			Regulative Total	Tidying	Tidying Total	Grand Total
Team and Participant	Creating awareness	Alleviating lack of knowledge	Creating shared understanding	Generative collaborative actions		Projective	Regulative	Relational		Tidying		
B	15	29	16	115	175	27	59	6	92	79	79	346
B1	5	4	4	26	39	4	7	4	15	20	20	74
Comment	2	1	3	9	15		5	3	8	1	1	24
Commit		3	1	14	18	3	1	1	5	19	19	42
Issue	3			2	5	1	1		2			7
PR Comment				1	1							1
B2	2	9	4	28	43	1	10		11	25	25	79
approval comment							2		2			2
Comment	1	1	2	6	10		4		4			14
Commit		4	1	7	12	1	2		3	25	25	40
Issue	1	4	1	7	13		2		2			15
PR Comment				3	3							3
review comment				5	5							5
B3	2	1	2	16	21	1	11	2	14	1	1	36
approval comment							1		1			1
Comment	2	1	2	4	9		10	2	12			21
Commit				3	3							3
Issue						1			1	1	1	2
PR Comment				4	4							4
review comment				5	5							5
B4	5	7	4	29	45	12	26		38	14	14	97
approval comment			1	1	2		2		2			4
Comment	3	3	2	10	18	4	19		23			41
Commit	1	2	1	11	15	5	3		8	13	13	36
Issue	1	2		4	7	3	1		4	1	1	12
PR Comment				2	2							2
review comment				1	1		1		1			2
B5	1	6	2	9	18	3	4		7	7	7	32
Comment		1	2	4	7		4		4			11
Commit		4		3	7	3			3	7	7	17
Issue	1	1		2	4							4
B6		2		7	9	6	1		7	12	12	28
Comment		1		2	3							3
Commit				2	2	6	1		7	12	12	21
Issue		1		1	2							2
PR Comment				1	1							1
Pull R				1	1							1
Grand Total	15	29	16	115	175	27	59	6	92	79	79	346

5.4.1. Epistemic dimension of actions

5.4.1.1. Creating awareness

Clarify goal

The interaction data provided insight into what the team saw as necessary to reach their goals, for example, a completed checklist item "Research on LDEs", and an Issue headed "Please add files, links or names of pedogogical research that supports our scenarios / 2025 vision." Analysis showed other goal-focused work toward task completion expressed in terms of knowledge object construction: "finalised", "updated", "draft…is needed", and "is required", and where an "aim" is expressed, it is to "complete this weeks tasks".

Identify needs

Team B looked for shared insights around the collaborative environment, asking for help in some cases directly. There are also examples of interactions that appear intentional sharing of useful information, for example, “I had to copy & paste the branch back into the master- couldn't work our easier way. This is now incorporating all our changes”, where B4 is sharing knowledge about how to use the environment as well as reporting what’s been done to incorporate everyone’s work.

5.4.1.2. Alleviating lack of knowledge

Structure and organising knowledge

Team B showed elements of organising and structuring their knowledge, for example, a request for pedagogical sources, and a Word document containing quotes copied and pasted from an educational technology report, with questions for consideration in the group’s design, for example, “Do we need to have a function within our learning platform where teachers can simply upload audio in response to learner’s questions???”. However, there is no further mention or evidence of these resources being used after their creation.

The team engaged in some in-depth discussion around the idea of ‘learning styles’, with one team member using academic references to support their position that they were a contentious area of theory, and others drawing on what they had heard from lecturers or “the literature I've gone through so far.” There was an attempt by a team member to engage others in an explanation of a preference for the terminology “Machine Learning” over “Artificial Intelligence” (AI), which was picked up by another team member in their modelling, and subsequently unilaterally overturned throughout the repo by another team member.

A team member from Team B also created an intermediate knowledge object to capture their design critique rationale and learning process.

5.4.1.3. Creating shared understanding

Discuss drafts in group meetings.

As well as working on knowledge objects after them, we can also see from mentions in their comments that Team B planned to discuss their knowledge objects in group meetings.

5.4.1.4. General collaborative actions

Generate numerous ideas that are discussed, considered, rejected and reconsidered

Team B did engage in discussions about draft knowledge objects in GitHub, but did not generate a wide range of ideas or reconsider ideas as a group. Most drafts were finalised without substantial discussion or significant changes. The GitHub data does not reveal an observable knowledge generation process with feedback focused on specific aspects of the diagram or code.

We can see efforts to generate shared meaning through discussion, with contributions to the discussion about pedagogical theory varying from sharing citations to sharing citations with "takeaways" relevant to the team's design to also including links and specific points about the relevance to the article to specific features of the team's knowledge objects. Several comments in this issue indicated that the team members were able to integrate others' explanations.

Develop knowledge objects after shared understanding reached in group discussions

There are GitHub interactions that show that the team engaged in discussions around the creation of the shared knowledge objects during their development, and others that might indicate that the search for shared understanding occurred after individual attempts at creating the narratives, diagrams and code. Table 23 below shows excerpts from all four interactions.

Table 23: Excerpts from GitHub interactions contrasting comments indicating that knowledge objects were developed after shared understanding took place with those indicating that might not have occurred.

Reference	Comment
comment	I hope my changes reflected what we discussed last Wed!
comment	But for the others, let me know if I reflected what we discussed during the meeting.
Issue	I have put in **bold italics** phrases that I would like others to check are correct please. I am not sure if I am using correct terminology or even that I have correctly understood (not feeling confident at this stage).
comment	One of my tasks for this week was for [B2] and I to "_Design Critique [instructor's] ticket - Make your ideas for including design critique in an LDE concrete by specific use case and interaction sequence diagrams_". I have gone to do this and realised I am not completely sure what it means - because I feel that our second use case "at a micro level" does this well. Sorry if I have misunderstood what I needed to do. Any suggestions/clarifications would be very appreciated!

Develop a systematic feedback process

There is evidence that agreement from probably two other team members was part of the workflow and that feedback was sought. Although there appears an established document approval process, almost as many interactions simply instruct the other team members to "feel free" to change the knowledge object, or to "scrap it".

There were several interactions where feedback was both explicitly sought and provided, and others where the team member did not explicitly ask for feedback but tagged other team members with the GitHub *review_requested* workflow function. This indicates that in some instances meaning continued to be negotiated through the feedback process.

In other cases, feedback was not explicitly sought and team members did not persist in a deep understanding of the knowledge object or development of its quality. For example, B5 adds a narrative, diagram and code for a dashboard use case with the comment “I have added a Dashboard. Was really unsure about it. Doesnt look as I wanted it to, but I dont have any more time to devote to it. I really wnated to try and integrate the data button more, but will try later on if I have time.”. Their document edit narrative has typographical errors, the new diagram does not display, the editing has broken the display of the other diagram in the document, and the code is not bracketed so displays as text. These problems are all visible to the author in the GitHub editor, however they have chosen to Commit the document as done regardless. The document was edited to replace the broken diagrams and code by B4 in the following two days (and remove B5’s self-attribution in the text).

In another instance, B6 requests feedback on what is described as an “immersive learning activity”, attempting to commit the document to the master branch despite errors. After feedback from B1 that the diagram does not display, B6 makes several attempts at resolution, and when the diagram displays correctly B4 provides feedback on both the model design and narrative. The author does not respond, and does not incorporate the feedback in their design.

Prepare report collaboratively

Generally, the approach to knowledge object construction appeared individual, with a task division approach visible early in the project. The interaction data indicates that team members generally worked without incorporating the ideas of others, raising an Issue and Pull Request when they wanted to merge their work to the master branch with sparse elaboration on the underpinning ideas or theoretical issues they encountered during development. We can see that where two team members were working on different aspects the same model, they did not work together, and when B1 asks for help with creating a narrative for their assigned diagrams, the response by B2 is to simply create the narrative and then raise a pull request for it, rather than discuss it with their colleague.

There are, however, two notable exceptions. One detailed exchange Team B had was in relation to a major edit one team member had made to the team’s *README*, intended to simply reflect the current repo ‘state of play’, but which this team had adapted to reflect their design rationale. Another team member used in-text review comments (the only use of this feature across the teams) to make two suggestions, and in their third comment asked what the other team member had meant by “style of learning”. In the following sequence of comments team members draw on both personal experience and theory in their discussion around the validity of this concept, in the end deciding to avoid the term and the original author changes it to “current level of knowledge specific to the subject to be learnt, as well as relevant learning goals and interests”.

There were other attempts to work collaboratively, a request for input on ideas around terminology to do with how the learning environment software and teacher provide feedback to the learner, and clarification on the use of the terms ‘learner’, ‘student’ and ‘user’ generating comments from four of the five team members. Another conversation that entered into detail was about a different part of the same edit, in the same document, with the author who used the term ‘learning styles’ providing definitions of naturalistic and authentic assessment to support the inclusion of both methods of learner data collection within the learning design environment the team were conceptualising. Three other team members then suggested additional data collection and feedback methods that could be incorporated into the idea, which were accepted in principle by the original editor but not incorporated in the knowledge object. No other knowledge object generated this level of theoretical or discursive engagement.

The period prior to task finalisation generated a range of activity and further confusion for the team, as several team members independently made changes to the shared knowledge objects, potentially outside the team’s previous approval processes. Where two team members had negotiated a change to the terminology “machine learning” (or MLA) in preference to “artificial intelligence” (or AI) as a considered decision, a different team member comments “Please note that I took the chance and changed Machine Learning to AI to have a consistent use of words in the ReadMe file - but if the group does not feel comfortable using this terminology I am happy to change it back.”. However, the comment is not on the Issue that was raised for the edits to the file in question, and on that issue the conversation was focused on vigorous discussion about the question of whether ‘learning styles’ should be included as a pedagogical approach so it is likely that only the one other team member who commented – who did not participate in the earlier discussions - saw this message. This division of conversations appears to confuse the team members as well, with the final comment by the author of both these Issues “I could not find everyone suggestions”. Another example is the design critique document and associated use cases, which ended up spread between two Issues because one thread was discussing “use cases” and one “design critique”.

A similar example is where B2, B1, B4 and B5 agreed on how to refer to the roles in the knowledge objects: “learner is better than student, as it has a broader definition and may apply across other sectors”, and “define between user and teacher as I think when people think user they will think of the learners. I think teacher is best for now - even though in future we are referring to them as facilitators”. However, a different team member changes all instances of ‘learner’ back to ‘student’, with the Commit comment “Typos, consistency and standardisation I have fixed all typos (that I have identified). I have also standardised the language - student is used throughout instead of 'learner'. I have fixed up some of the interactions as there was some confusion between learning designer and database at points.”. They also remove the word ‘facilitator’ which had been agreed as part of the portmanteau ‘teacher/facilitator’ and preferencing the word “user” to “student”, which the others had agreed was not their intention, deciding on “learner” as being broadly applicable across contexts, with “user” having a different meaning. The comment “Typos, consistency and standardisation” does not reflect the full scope of changes which as well as the change in terminology from “learner” to student throughout Team B’s work, encompass a shift in the *Interactions.md* model construction from feedback being provided to the learner from a data base developed by machine learning to being provided by a learning design.

5.4.2. Regulative dimension of actions

5.4.2.1. Projective

Agree on collaborative strategies

We can see there was an agreed workflow that was renegotiated during the project, but not whether Team B had a deliberately agreed collaborative strategy. Deliberate actions toward joint knowledge object development are visible in GitHub Issues and comments, for example, “Research on LDEs”, in a list that includes “Come up with use cases for different platforms”.

5.4.2.2. Regulative

Monitor object development and quality

While there was planned task division, shared responsibility for consciously monitoring the knowledge object development and quality was lacking, and the early use of Issues to track task status did not seem to be maintained. The interaction data illustrates confusion around the task, the knowledge objects and the process just two weeks before the task was finalised. We have also seen that there are interactions where team members ask others to “check” their work, to let them know if they have “made any major mistakes”, if they are “wrong”, or if things are “not resolved”.

Team B sometimes used the GitHub Commit, Issue or Pull Request comment to document the work that had been done on the knowledge object or the rationale behind it. Many Commits were made with either the default comment, for example, “Update <document>”, or something generic, for example “I've updated the readme”. In some cases, comments are idiosyncratically labelled with a reference that is confusing to GitHub, for example. “Updated Narrative” and then a “#” symbol followed by the numeral representing the sequence number of the related diagram in the document which had been updated. GitHub understands the “#” notation to refer to the Issue with that number, and this use resulted in incorrect cross-links to those references being appended to each Issue page, as shown at Figure 29. More than a third of Team B’s actions had no comment, but there were comments that contained insights into the problem that the action had solved.

Figure 29: Partial screen shot illustrating unrelated Commits linked to a GitHub issue page because their comment uses the character "#" and a number in the text.

5.4.2.3. Relational

The relational comments in Team B’s GitHub data were thanks for contributions.

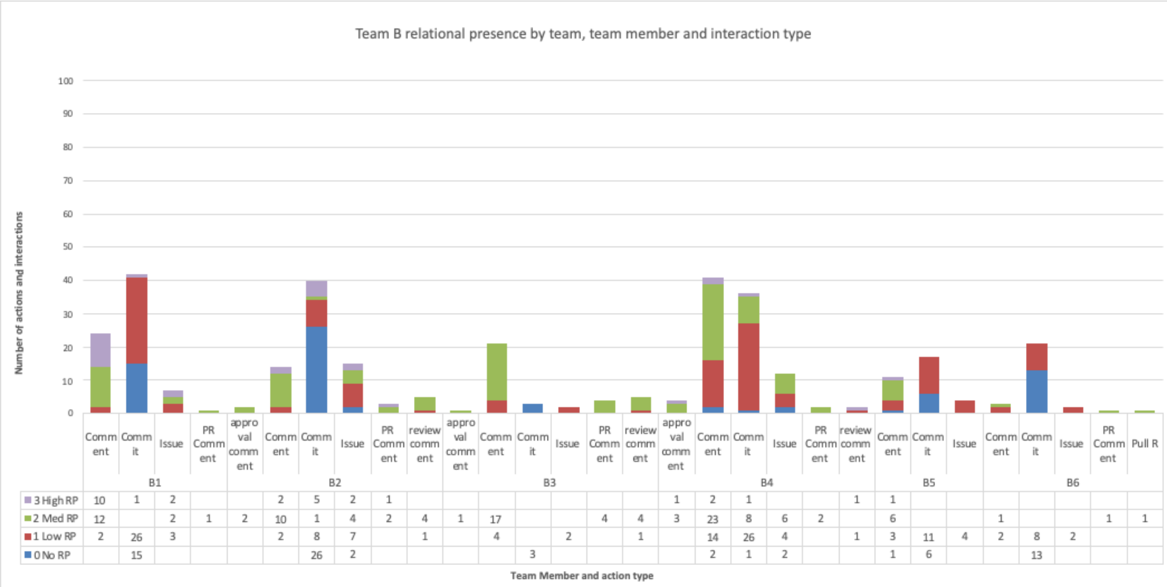
5.4.3. Other dimensions

There was no social chat in Team B’s interactions.

5.4.4. Emergent theme: relational presence

Team B used polite language with other in many interactions, without much warmth or humour. More than half their overall interactions had low or no relational presence, and nearly half their total relational presence was provided by two of the six team members. A breakdown of interactions and their relational presence is at Figure 30 with some examples at Table 24.

Three people from Team B of the six added a photo to the repo.



	B1 Comment	B1 Commit	B1 Issue	B1 PR Comment	B2 approval comment	B2 Comment	B2 Commit	B2 Issue	B2 PR Comment	B2 review comment	B3 approval comment	B3 Comment	B3 Commit	B3 Issue	B3 PR Comment	B3 review comment	B4 approval comment	B4 Comment	B4 Commit	B4 Issue	B4 PR Comment	B4 review comment	B5 Comment	B5 Commit	B5 Issue	B6 Comment	B6 Commit	B6 Issue	B6 PR Comment	B6 Pull R
3 High RP	10	1	2			2	5	2	1								1	2	1			1	1							
2 Med RP	12		2	1	2	10	1	4	2	4	1	17			4	4	3	23	8	6	2		6			1			1	1
1 Low RP	2	26	3			2	8	7		1		4		2		1		14	26	4		1	3	11	4	2	8	2		
0 No RP		15					26	2					3					2	1	2			1	6			13			

Figure 30: Team B relational presence by team member for Commit, Issue, comment, approval comment, commit comment, pull request comment and review comment interactions.

Table 24: Examples of Team B's interactions at high, medium and low relational presence (RP) levels.

Reference	RP	Comment
comment 1172	High	Thanks a lot, [B4]! I'll work on the interaction and component diagrams tonight. Let me know @[B2] if you're online so we can chat about it. Otherwise, just feel free to make Commits during your free time. Thank you!
comment 1471	Med	I think [B2] has created what we needed - but I could be wrong. Please let me know if I am.
comment 1185	Low	Hi All. I have fixes use-case 2 digram so now it is diaplayed. I have also *hopefully* created use case 1 and use case 3 (ideal). I cannot get them to display but you should be able to click on the link to view the image. If you are happy, can you please Commit to main branch

5.4.5. Team B's collaboration

The members of Team B displayed individual approaches to constructing knowledge about their environment together, however, there were instances when they shared useful information. There were also instances where the information shared was not an accurate reflection of what was done, considered in Section 6.3.5 of the Discussion chapter.

The GitHub interaction data showed that all team members contributed to the collaborative process and most to the shared knowledge objects to some extent, and that there is some difference between team members in both the nature and frequency of their contributions.

There was some evidence of decision making at group level, but monitoring of the shared knowledge objects was unsystematic.

There are indications of collaborative knowledge co-construction. However, feedback provide by others was rarely ncorporated by the original author.

5.4.6. Team B's agency

Table 25 shows that Team B demonstrated agency across both dimensions, with comment interactions equally balanced between epistemic and regulative behaviours. There was a high level of 'tidying' behaviour compared with advancement of the knowledge objects. Agentic behaviours were not evenly distributed across the team in any category. Relational presence in Commit comments tended to be at no or low levels, with comments more frequently classified as having medium or high relational presence.

Table 25: GitHub interaction type for Team B's comments, Commits, Issues /Pull Requests; approval, pull request and review comments, that are epistemic, regulative, or tidying for all team members by classification, relational presence and team member.

	Team Member and activity classification																					
	⊟ Epistemic						Epistemic Total	⊟ Regulative						Regulative Total	⊟ Tidying						Tidying Total	Grand Total
Activity type and relational presence	B1	B2	B3	B4	B5	B6		B1	B2	B3	B4	B5	B6		B1	B2	B3	B4	B5	B6		
⊟ **approval comment**				**2**			**2**		**2**	**1**	**2**			**5**								**7**
2 Med RP				1			1		2	1	2			5								6
3 High RP				1			1															1
⊟ **Comment**	**15**	**10**	**9**	**18**	**7**	**3**	**62**	**8**	**4**	**12**	**23**	**4**		**51**	**1**						**1**	**114**
0 No RP				1	1		2				1			1								3
1 Low RP	2	2	2	6	2	2	16			2	8	1		11								27
2 Med RP	8	6	7	10	4	1	36	3	4	10	13	2		32	1						1	69
3 High RP	5	2		1			8	5			1	1		7								15
⊟ **Commit**	**18**	**12**	**3**	**15**	**7**	**2**	**57**	**5**	**3**		**8**	**3**	**7**	**26**	**19**	**25**		**13**	**7**	**12**	**76**	**159**
0 No RP	2	3	3		2	1	11	2	2				6	10	11	21		1	4	6	43	64
1 Low RP	15	3		11	5	1	35	3	1		5	3	1	13	8	4		10	3	6	31	79
2 Med RP		1		3			4				3			3				2			2	9
3 High RP	1	5		1			7															7
⊟ **Issue**	**5**	**13**		**7**	**4**	**2**	**31**	**2**	**2**	**1**	**4**			**9**			**1**	**1**			**2**	**42**
0 No RP		2		1			3											1			1	4
1 Low RP	2	7		1	4	2	16	1		1	3			5			1				1	22
2 Med RP	1	3		5			9	1	1		1			3								12
3 High RP	2	1					3		1					1								4
⊟ **PR Comment**	**1**	**3**	**4**	**2**		**1**	**11**															**11**
2 Med RP	1	2	4	2		1	10															10
3 High RP		1					1															1
⊟ **Pull R**						**1**	**1**															**1**
2 Med RP						1	1															1
⊟ **review comment**		**5**	**5**	**1**			**11**				**1**			**1**								**12**
1 Low RP		1	1				2				1			1								3
2 Med RP		4	4				8															8
3 High RP				1			1															1
Grand Total	**39**	**43**	**21**	**45**	**18**	**9**	**175**	**15**	**11**	**14**	**38**	**7**	**7**	**92**	**20**	**25**	**1**	**14**	**7**	**12**	**79**	**346**

5.5. Classification of GitHub actions/interactions: Team C

A breakdown of knowledge object and communicative actions and interactions in each dimension and category for Team C is at Table 26.

Table 26: Team C comments, Commits, Issues, Pull Requests and review comments, by team member and classification.

	⊟ Epistemic				Epistemic Total	⊟ Regulative			Regulative Total	⊟ Tidying	Tidying Total	Grand Total
Team and Participant	Creating awareness	Alleviating lack of knowledge	Creating shared understanding	Generative collaborative actions		Projective	Regulative	Relational		Tidying		
⊟ C	26	46	57	153	282	40	140	16	196	126	126	604
⊟ C1	7	11	9	26	53	12	14	2	28	17	17	98
Comment	4	4	9	15	32	2	12	2	16			48
Commit	3	2		9	14	6	1		7	17	17	38
Issue		5		1	6	4	1		5			11
Pull R				1	1							1
⊟ C2	3	9	8	26	46	4	22		26	9	9	81
Comment	2	2	8	14	26	1	14		15			41
Commit	1	5		8	14	2	3		5	9	9	28
Issue		2		4	6	1	4		5			11
Pull R							1		1			1
⊟ C3	4	15	23	31	73	7	45	6	58	26	26	157
Comment	2	9	21	14	46	4	37	6	47			93
Commit	1	5	1	14	21	1	3		4	26	26	51
Issue	1	1	1	3	6	2	5		7			13
⊟ C4	2		2	18	22	7	17		24	44	44	90
Comment			1	9	10	1	9		10			20
Commit	2			6	8	6	8		14	43	43	65
Issue				1	1							1
Pull R				1	1							1
review comment			1	1	2					1	1	3
⊟ C5	1	4	2	20	27	4	16		20	10	10	57
Comment			2	7	9	2	7		9			18
Commit	1	3		11	15	1	2		3	10	10	28
Issue		1		1	2	1	7		8			10
Pull R				1	1							1
⊟ C6	9	7	13	32	61	6	26	8	40	20	20	121
Comment	4	1	10	13	28	3	20	6	29			57
Commit	3	3	1	14	21	2	2		4	19	19	44
Issue	2	3	2	4	11	1	4	2	7	1	1	19
Pull R				1	1							1
Grand Total	26	46	57	153	282	40	140	16	196	126	126	604

5.5.1. Epistemic dimension of actions

5.5.1.1. Creating awareness

Clarify goal

Team C discussed their goals in their asynchronous interactions as well as in meetings, returning to key points from the task to re-evaluate their ideas. The GitHub data also shows them discussing how they will find the necessary resources to move forward.

Identify needs

Team C engaged in activity that indicated they could identify their needs and alleviate their lack of knowledge, for example, while one team member sought additional information from the instructors about technical issues with the online meeting room, creating files and folders in GitHub and the task itself, another commented “an extensive search online and I couldn't find anything, not on reference guides, nor on cheat sheets, not anywhere...” when asking a team member for help in constructing their diagram. In this conversation C3 describes the intended modelled outcome and the model element they are not able to complete. After asking a clarifying question, C2 proposes a solution and posts the diagram and associated code, explaining the element that needs to be included for C3's intended outcome to be modelled. C3 is able to explicitly describe their new understanding in a comment "Ohhhh I see! I needed that "as CL" part and then specify their connections! I knew about the -down-> notation but I was missing the "as CL". Great! I'll fix it now and then ask everybody to check it. Thanks @[C2] !!". The same team member also used resources developed by the instructors later in the project to resolve a conflict between saved document versions, commenting "I've made changes that brought about conflicts. I then went to the wiki and followed the steps on how to resolve conflicts but I need to merge this to see what happened and if my changes are gonna show or not.".

5.5.1.2. Alleviating lack of knowledge

Structure and organise knowledge

The GitHub interaction data shows that Team C took deliberate steps to address their need for more theoretical understanding to address different areas of the collaborative task, engaging the group with questions and suggested solutions. In response to the instructor-initiated design critique task, a team member first suggests taking a 'bigger picture' look. After starting research on design critique in instructional design and finding limited material, they then report their realisation that as "the whole learning experience is really also about user experience, I was then able to find tons of stuff on UX design critique.", sharing two resources to the team. A different team member agrees that one of the resources is expert, and suggests an additional design critique resource.

We can see that these resources were used not only here but in a concurrent instructor-initiated task that asked the teams to incorporate a design critique element in the instructional design system model they were developing, because in a comment C2 summarised "in reading the articles here and in others online about design critique processes…" into a possible structure for a use case. This was in response to an expressed lack of knowledge, which also drew together the work done so far and recent information from the instructor "Is this regard and taking into account [instructor's] questions, I think that we also need to consider: - How do we engage experts to contribute to the design critique? (motivational aspect) - How do we capture expert's feedback in a way that the "personalisation engine" o the intelligent system can read and interpretate the information?".

5.5.1.3. Creating shared understanding

Generate and negotiate shared meaning

As well as engaging in discussions around the parameters of the project task, Team C spent time in GitHub generating and negotiating meaning by asking questions about the features and functions of their model designs, and the way in which they connected with each logically. Early on in the collaboration they decided that the models would need to make sense as a coherent whole, and even when that meant extra work to re-align diagrams and code in line with new realisations, Their comments over the course of the project indicating that they continued to engage in rigorous discussion to ensure they were creating shared meaning.

Team C's discussions indicated they were able to use elaboration to move through confusion and connect different ideas conceptually. When team member asked questions to clarify the way in which these models integrated with the others that had been developed, the original modeller responded with an explanation and request for further elaboration of the question that would allow them to understand more deeply. As the questioner elaborates, the point they are making about the representation of their system's capacity to personalise courses becomes clearer, and the original modeller is able to respond with an analogy to one of the resources which had been provided earlier to explain the level of detail which the diagram depicts. Another team member is able to bridge the different ways the others are framing the discussion and suggests a solution, which makes sense to the original modeller as he expresses "that's true. The reason why I only put the descriptor on one of the dotted arrows is because all the like arrows mean the same. So all the dotted arrows mean that the user can choose to input. Should I put the same descriptor for each of the dotted arrows then?". Another understanding follows; that this could incorporate an aspect of the design critique task the team have been doing for the instructor. After the feature is incorporated, it's clear to the team that this does not align with either of the example models. They discuss the original intention of the task, which was to agree on simple use cases, and conclude that the addition is not needed as it is captured in another model. The change from use case approval to design critique incorporation is noted by another team member in a comment"@[C2] Yes, I agree with you. I got confused because I understood that we were aim to develop ideas about how to integrate the design critique functionality to our model. That's why it made sense to me to build on [C1’s] sequence diagram. I'd stay with your last model, adding [C1’s] feedback.”

Share insights

While as a group Team C most often searched for solutions by asking other team members or by individually searching elsewhere, they were good at explaining what they found to each other. They used concrete references to documents, sources, and often placed their suggestions either within the task or broader professional context. For example, when a merge has not been successfully completed one team members explains to another “@[C1] you see? it says "closed with unmerged Commits" 😮 and his use case is still in a branch not in the master, that's why you can't see it in the UseCase.md repo.”

They also worked hard to develop their understanding of the task and environment. When C3 first tries to model a component diagram, they comment “I think this looks more like an activity diagram. I had a hard time creating the database. I was just experimenting with PlantText. Also, I don't know whether it's correct to post this here or in the Component.md file?”, and described the strategy they used to understand the modelling notation “I went to a reference guide of PlantText for component diagrams and used a template and then worked my way around it! (some things are missing tho). Anyways, a lot of trial and error, but first I designed the map on paper. It makes total sense to do that, put the content after so it is generated by the software instead of the designer.”.

While one team member had sought to resolve a question about the task by emailing a diagram they had prepared to the instructor and asking if it was valid, other team members stepped in to the conversation, with one suggesting a conceptual explanation along with an empathetic expression of shared lack of understanding. A third team member confirms the conceptual explanation and disambiguates the type of model from other relevant types, and we can see that it is the same team member who has been using reference materials to develop their modelling skills, and who suggests “(Shouldn't we probably be reading the literature to get more ideas?)”.

Discuss drafts in group meetings

While the team meeting notes will be analysed separately for the purposes of triangulating the GitHub data, we can tell from these interactions that the development of the knowledge objects was discussed during group meetings, and from Commit comment “Updated Parent Scenarios Post Meeting” that changes were made in consequence.

5.5.1.4. General collaborative actions

Generate numerous ideas that are discussed, considered, rejected and reconsidered

Just a week before the task was due for submission, Team C were introducing new ideas that overcame some of the conceptual barriers they had been struggling with, and C6 had achieved an insight and proposed a new model for a “smart” course design system to the team as a proof of concept. The team realised that the ‘CoachU’ code they had worked with early in the project was a good foundation for the new model, and worked out how to build on it to design the necessary integrations with other systems. This led to a broadening of the thinking in line with the ‘futuristic’ brief, and an updated model based on a recent article on application programming interfaces and artificial intelligence being included across the final knowledge objects. While the conversation is too long to include here in full, you can read it at Appendix I.

Idea generation began early in the project with comments showing input on suggested models was provided at both abstract and concrete levels as part of an agreed workflow process and also a genuine elicitation of individual ideas toward mental model alignment and shared model co-construction.

Develop knowledge objects after shared understanding reached in group discussions

The GitHub data shows Team C engaging in discussions to create shared understanding about all aspects of the task. As well as having a planned approach to collaboration and a coordinated document approval workflow, team members frequently asked questions, requested clarifications, made suggestions and celebrated reaching shared understanding. We can see that those discussions took place in both group meetings and asynchronously online with five Issues focused around team members aligning their mental models before moving forward with their shared knowledge objects. This is summarised well at this excerpt from a comment “So, as a team, I think we need to take a moment to look at the various models and see where we need to make changes (most likely in the parent scenario model) in order to keep the logic flow consistent throughout all the models we are creating. At least in terms of what is coming in and going out of each component so that it is consistent and would be able to slot into the larger "puzzle" - think of it as a magnified portion of the larger scenario.”.

Develop systematic feedback process

The interaction data also reveals an agreed feedback mechanism, with a comment concerned that these discussions may not be retained once the Commit is complete (this is not the case in GitHub): "I know in our meeting we said we were going to do critiques in the pull requests for all our models, but I think the comments in pull requests get deleted once you merge the request, so while I think it's a good idea to have the conversation in the pull request before we merge it, we may want a summary of the conversation recorded somewhere so we can refer back to it."

Team C regularly sought and responded to feedback from other team members, as can be seen by the interaction data from Commits, Issues and comments as well as the agreed workflow process articulated in an Issue "Added narrative. Added an team pull request model agreed on last meeting.". When a model was proposed, a Pull Request was raised and reviewers assigned from the team to critique it. This was not only an opportunity to get a 'tick of approval', but also a chance for the developer of the model to ask questions of the reviewers around issues they had not quite themselves resolved, for example, the exchange illustrated at Figure 31.

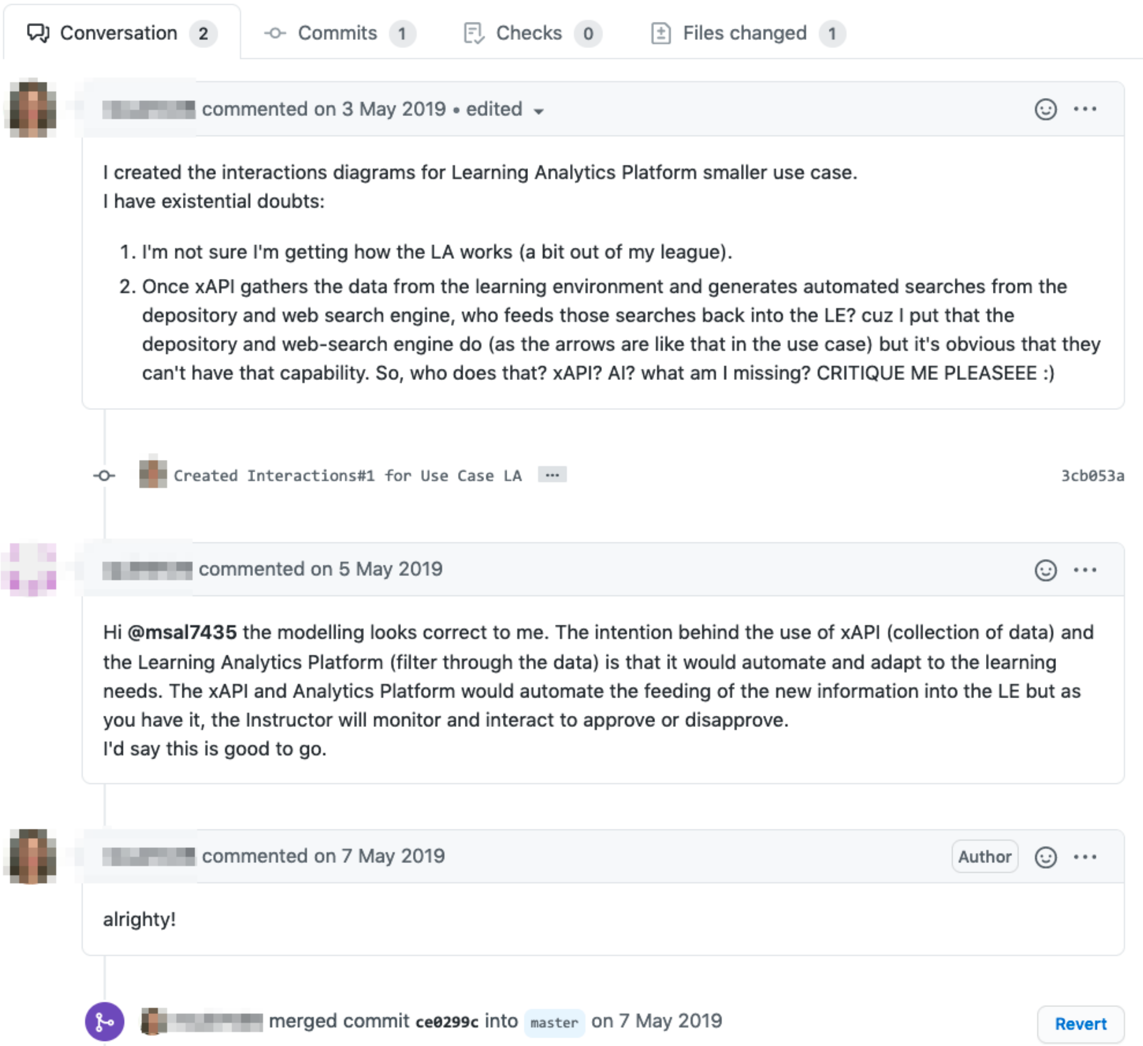


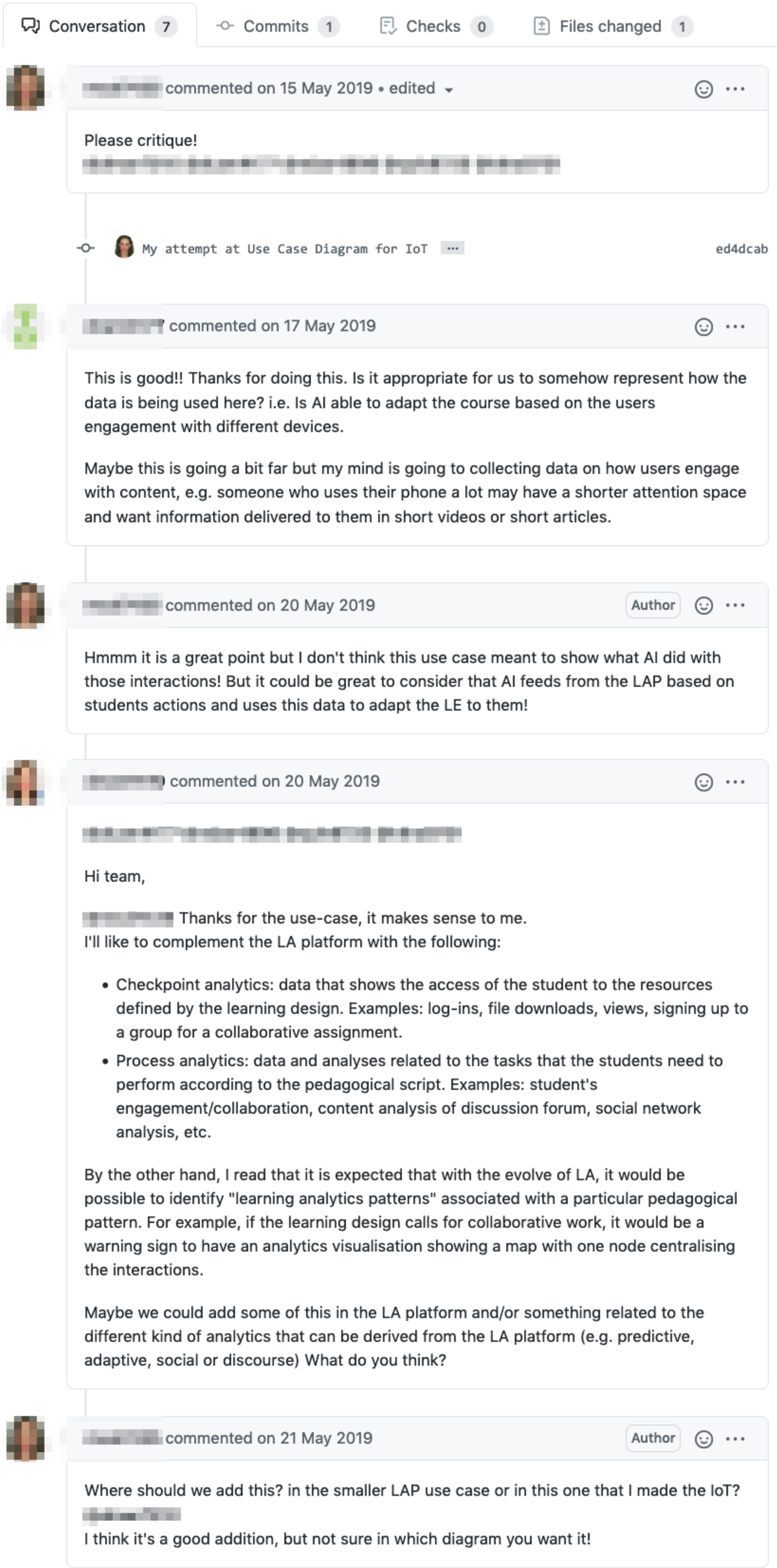
Figure 31: Screen shot of request for critique on model validity and coherence in Team A as part of systematic feedback process.

While the feedback process was embedded in the team workflow, the request was also often explicitly stated in an issue comment, and it is clear from the GitHub interaction data that Team C incorporated the feedback received from other team members iteratively during the development of their knowledge objects throughout the course of the project.

Team C engaged in feedback activities at team and individual levels. For example, seeking and acting on group feedback can be seen in the discussions around whether to use ‘repository’ or ‘’’depository’, which had been used interchangeably in document drafts. We can then see the group’s decision enacted by several team members on different documents, with further consistency checking occurring prior to task submission. More complex coordination was required when a ‘parent’ model was changed, requiring adjustments across the set which the team had designed as an integrated and coherent whole, and we can see an understanding of the position of the model within the set, as well as the status of the other objects in development, in the comment that accompanies a major update to *Components.md*: “Hi guys, I made many changes to this repo, following the logic of the main use case scenario "Adaptive LD System". 1. I've eliminated Component #1 as per [C6’s] request since it was an outdated model, so I replaced it by the Component Diagram #2 which is now #1. 2. I added a narrative to #1. @[C4] would you mind taking a look at the "Personalisation Layer" description? I'm not sure if the narrative reflects the components you modelled from which I fed to create that layer. 3. I've changed narrative of Component Diagram #3 "Component Diagram based on Personalisation Engine". 4. I haven't added narrative to "Component Diagram #2 based on Learning Analytics Platform" because I didn't model it and I think the one who modelled it should add the narrative.”.

When a use case diagram for the Internet of Things (IOT) was proposed in a pull request, C3 explicitly asks for feedback, and three team members ask specific questions about the detail level of the model, its components and processes, and the appropriate location for the model within the overall set which have been constructed by the team. While the thread is quite lengthy, it is worth reproducing in its entirety at Figure 32 below to illustrate how the modeller responds to each feedback and negotiates not only what should be in the final version, but also how the integration of other knowledge objects should be handled.

Team C were also able to manage when feedback indicated their work was not what they intended. In one instance, C6 asks for feedback on their interaction diagram, only to realise from C3’s response that they have updated the wrong model. Liberal use of capital letters, emojis, punctuation and sharing of the pressures of university work follow and the issue is closed without issue. Empathy and relational comments were present throughout Team C’s work, and are considered further both in Section 5.5.4 and in the Discussion chapter.


Conversation 7 | Commits 1 | Checks 0 | Files changed 1

[redacted] commented on 15 May 2019 • edited

Please critique!
[redacted]

My attempt at Use Case Diagram for IoT … ed4dcab

[redacted] commented on 17 May 2019

This is good!! Thanks for doing this. Is it appropriate for us to somehow represent how the data is being used here? i.e. Is AI able to adapt the course based on the users engagement with different devices.

Maybe this is going a bit far but my mind is going to collecting data on how users engage with content, e.g. someone who uses their phone a lot may have a shorter attention space and want information delivered to them in short videos or short articles.

[redacted] commented on 20 May 2019 Author

Hmmm it is a great point but I don't think this use case meant to show what AI did with those interactions! But it could be great to consider that AI feeds from the LAP based on students actions and uses this data to adapt the LE to them!

[redacted] commented on 20 May 2019

[redacted]

Hi team,

[redacted] Thanks for the use-case, it makes sense to me.
I'll like to complement the LA platform with the following:

- Checkpoint analytics: data that shows the access of the student to the resources defined by the learning design. Examples: log-ins, file downloads, views, signing up to a group for a collaborative assignment.
- Process analytics: data and analyses related to the tasks that the students need to perform according to the pedagogical script. Examples: student's engagement/collaboration, content analysis of discussion forum, social network analysis, etc.

By the other hand, I read that it is expected that with the evolve of LA, it would be possible to identify "learning analytics patterns" associated with a particular pedagogical pattern. For example, if the learning design calls for collaborative work, it would be a warning sign to have an analytics visualisation showing a map with one node centralising the interactions.

Maybe we could add some of this in the LA platform and/or something related to the different kind of analytics that can be derived from the LA platform (e.g. predictive, adaptive, social or discourse) What do you think?

[redacted] commented on 21 May 2019 Author

Where should we add this? in the smaller LAP use case or in this one that I made the IoT?
[redacted]
I think it's a good addition, but not sure in which diagram you want it!

Figure 32: Screen shot illustrating feedback on IOT model and the modeller's responses.

Prepare report collaboratively

While Team C did assign and individually construct models, code and diagrams, their work was interdependent and reporting was collaborative. Team members reviewed their modelling in light of others' work, for example, C1 comments "I have made an attempt to model the sequence of entering info and retrieving from the Personalisation Engine and the Cloud Depository. BUT, as I said in the comments to [C2's] pull request with the new Use Cases, I'm not sure that they are all aligning now so I'm not sure if this diagram is actually accurate for what we want to do.". Similarly, C6 comments, "I will wait for @[C2] to update his narrative and for him to double check that the use scenario model reflects your understanding as written here and then I will mirror these changes in my interactions model."

This being said, in the weeks prior to task submission, there was a period of activity focused on asking individual team members to modify their contributions for consistency and coherence with the whole, set out at "Group to do list", and a link is provided to a Google slides document for individual uploads to a presentation that will be done by the team in class. But the data shows that the presentation is still a collaborative product, as C3 discusses one team member adding another's updated model to their part of the presentation, and C6 confirms "I will also add to the slides tomorrow morning but all I am adding are the definitions we agreed upon as I will be introducing the system through the readme (which I will also update tomorrow morning).".

While the whole team was engaged in what we are calling 'tidying', one particular team member made changes to the shared knowledge objects that exceeded this remit. While this is considered further in the Discussion chapter, for convenience I've labelled this pejoratively 'bad tidying' as it reduces the quality of the knowledge objects and the collaboration, While the stated purpose was "Minor amendments spelling etc", edits were made that unilaterally overturned a decision made the previous month. In another edit, the same team member made less disruptive changes, without prior consent and the comment that they would change them back " if the group prefers.". This approach is in contrast to the way the group had been approaching knowledge object development for the preceding weeks, in which this team member had been only occasionally engaged.

There's a whole series of bad tidying by the same team member in Week 11 and in Week 12 class time (presentation week), with changes made unilaterally and the note "happy to remove if no one else agrees" despite processes about agreeing having been agreed to in meetings and reified in documents and models, and in contrast to other team members' approaches to editing. Nor did they review other well-formed documents to resolve issues, as their indirect request for help with formatting in Markdown in presentation week shows: "I know this is a minor change so apologies for the pull request but I have had this issue multiple times where the image appears as it should on my screen but for others it doesn't appear. I'm still not 100% sure why that is (anyone?) but I wanted to see if this works before I Commit another broken link to the master.". Committing minor changes to the master branch was explicitly permitted, but these changes were not minor.

All group members contribute

The GitHub data shows that all team members contributed to the collaborative process and most to the shared knowledge objects. For most of the project, almost all team members were actively engaged in contributing in both epistemic and regulative dimensions, with some team members also contributing interactions with a purely relational purpose.

Team C also valued all team members' contributions, with explicit references to team members evolving ideas that others have proposed.

This does not necessarily indicate that all team members contributed equally to the development of ideas in the project, the volume of work, or the monitoring of the knowledge object development status or quality. Something indicative of one team member being out of step with the others is a 'backward' merge of the team's repo into a team member's branch the week before task submission, which indicates that the three merged knowledge object versions in their branch were so incompatible with the master branch that only a complete overwrite would align them. This occurred again in the final week with the other two assessable knowledge objects.

5.5.2. Regulative dimension of actions

5.5.2.1. Projective

Agree on collaborative strategies

The GitHub data shows that Team C made a conscious effort to develop a shared collaborative strategy. Their first Issue comment invited shared input with "Let's brainstorm some ideas on how we will work together and then I would be happy to try to create a model in planttext (unless someone else has a burning desire to). We could create a model that plans out our week and assigns tasks to roles. If you like this idea, feel free to add to it. If not, let me know what you would prefer to do.", tagging all team members. They continue to negotiate ways of working together; after C3 posts an "attempt of a component diagram", C6 comments "Great start [C3]! I think this is a good way to work - someone just outputs something for us to workshop and generate ideas from.".

There is evidence of a structured approval process which evolved over the course of the project, and the team continues to negotiate this process in the early days of the project.

Team C did break down tasks within the team with an initial review of GitHub documents divided among team members. There was an instance where a particular team member had shown themselves to be reliable in constructing UML models, and after a series of models had been sent their way for amendment or repair, commented that others could "feel free to edit", as "I'd actually like to have a god at modelling something else next week.".

5.5.2.2. Regulative

Monitor object development and quality.

Although the team experienced some difficulties with the GitHub workflow in the early stages of the project that is visible in several Issues, Team C continuously monitored the quality and coherence of their knowledge objects throughout the project.

5.5.2.3. Relational

The relational comments in Team C's GitHub data were empathy with other team members, thanks for and recognition of contributions, and celebration of their team at the end of the project.

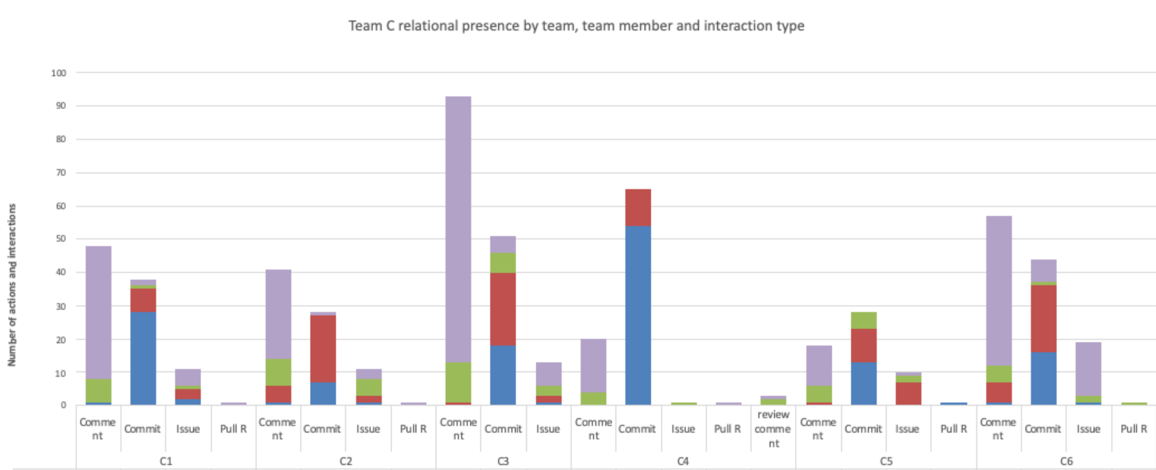
5.5.3. Other dimensions

There was no social chat in Team C's interactions.

5.5.4. Emergent theme: relational presence

Team C often discussed their project in GitHub interactions using natural and friendly language, with almost as many of their interactions having a high relational presence as those with no, low and medium relational presence together. Even when things were simply regulative, for example, responding to a request for clarification around models that appear to be duplicates in a group 'to do list at, communication between team members was cordial and warm "Hi [C6], thanks for this to do list. I'll eliminate Component #1 that I designed first, you're right, #2 is an update of #1. So, onto it now.". A breakdown of interactions and their relational presence is at Figure 33 with some examples at Table 27.

Two people from Team C of the six added a photo to the repo.



	C1				C2				C3			C4					C5				C6			
	Comment	Commit	Issue	Pull R	Comment	Commit	Issue	Pull R	Comment	Commit	Issue	Comment	Commit	Issue	Pull R	review comment	Comment	Commit	Issue	Pull R	Comment	Commit	Issue	Pull R
3 High RP	40	2	5	1	27	1	3	1	80	5	7	16			1	1	12		1		45	7	16	
2 Med RP	7	1	1		8		5		12	6	3	4		1		2	5	5	2		5	1	2	1
1 Low RP		7	3		5	20	2		1	22	2		11				1	10	7		6	20		
0 No RP	1	28	2		1	7	1			18	1		54					13		1	1	16	1	

Figure 33: Team C relational presence by team member for Commit, Issue, comment, and review comment interactions.

Table 27: Examples of Team C's interactions at high, medium and low relational presence (RP) levels.

Reference	RP	Comment
comment	High	LOLOLOLOLOL!!! The exhausting tiredness is taking the best of us all 😭 I was literally crying like a 5-year old 10 minutes ago. Emotional Breakdown. May the force be with us 🙏!
comment	Med	Yes happy with that and I think it is a great idea to still link to it in the readme.md
comment	Low	Also I can't remember how to add the PNG file of the UML so I just put in a link to the PNG instead. Can anyone remind me how to add this?

5.5.5. Team C's collaboration

Team C engaged in an energetic and shared approach to constructing knowledge about the task, environment and ways of working together. They went beyond the task specifications to bring new ideas, such as the Internet of Things model and the use case overcoming the limitations of AI being an ‘actor’, throughout the project. They took an active role in providing feedback and asking questions about each model and its integration with the other elements of their task. They responded to feedback received in a concrete way, with replies in comments and/or modifications to the knowledge object. They actively monitored their progress and engaged in shared efforts to advance their work.

The GitHub interaction data showed that all team members contributed to the collaborative process and to the shared knowledge objects, with some participants contributing more productively than others to the quality of the final report. While there is some difference between team members in both the nature and frequency of their contributions, the team's interactions generally had a strong relational presence.

5.5.6. Team C's agency

Table 28 shows that Team C demonstrated agency predominantly in the epistemic dimension, with more Issues and comments related to knowledge co-construction than updates to the shared knowledge objects. They also demonstrated agency in the regulative, relational and other dimensions. Agentic behaviours were not evenly distributed across the team in any category. Relational presence in Commit comments tended to be at high levels for Issues and comments, with Commits associated with no or low relational presence.

Table 28: GitHub interaction type for Team C's comments, Commits, Issues /Pull Requests; approval, pull request and review comments, that are epistemic, regulative, or tidying for all team members by classification, relational presence and team member.

	Team Member and activity classification																					
	⊟ Epistemic						Epistemic Total	⊟ Regulative						Regulative Total	⊟ Tidying						Tidying Total	Grand Total
Activity type and relational presence	C1	C2	C3	C4	C5	C6		C1	C2	C3	C4	C5	C6		C1	C2	C3	C4	C5	C6		
⊟ Comment	32	26	46	10	9	28	151	16	15	47	10	9	29	126								277
0 No RP	1	1					2						1	1								3
1 Low RP		1	1			3	5		4			1	3	8								13
2 Med RP	3	4	3	1	2	3	16	4	4	9	3	3	2	25								41
3 High RP	28	20	42	9	7	22	128	12	7	38	7	5	23	92								220
⊟ Commit	14	14	21	8	15	21	93	7	5	4	14	3	4	37	17	9	26	43	10	19	124	254
0 No RP	7	3	4	7	6	9	36	5	2		13	2	2	24	16	2	14	34	5	5	76	136
1 Low RP	5	10	9	1	6	7	38	1	3	2	1	1	2	10	1	7	11	9	3	11	42	90
2 Med RP			6		3		9	1						1					2	1	3	13
3 High RP	2	1	2			5	10			2				2			1			2	3	15
⊟ Issue	6	6	6	1	2	11	32	5	5	7		8	7	32						1	1	65
0 No RP	1						1	1	1	1				3						1	1	5
1 Low RP	1	1	2		2		6	2	1			5		8								14
2 Med RP		3	2	1		2	8	1	2	1		2		6								14
3 High RP	4	2	2			9	17	1	1	5		1	7	15								32
⊟ Pull R	1			1	1	1	4		1					1								5
0 No RP					1		1															1
2 Med RP						1	1															1
3 High RP	1			1			2		1					1								3
⊟ review comment				2			2											1			1	3
2 Med RP				1			1											1			1	2
3 High RP				1			1															1
Grand Total	53	46	73	22	27	61	282	28	26	58	24	20	40	196	17	9	26	44	10	20	126	604

5.6. Initial conjectures about the collaborative characteristics of each team

The findings in Sections 5.3-5.5 show that as well as differences between individual team members in the frequency and nature of their contributions, there are also differences between teams in the way in which they approach collaboration in the dimensions of activity, and differences in the manifestation of agency. From the GitHub data alone, these findings suggest each team's way of working together had specific characteristics in these epistemic and regulative dimensions. Table 29 shows a set of conjectures based on these results about how each team approached the collaborative process in those categories of activity which enable comparison across groups. These conjectures will be evaluated against a secondary data analysis in Section 5.8.

Table 29: Initial conjectures about the characteristics of the collaboration process by group based on the GitHub data alone.

Team A	B	C
Epistemic Actions		
Creating awareness		
Identification of needs and clarification of goals not visible in interactions	Identification of needs and clarification of goals not visible in interactions	Identification of needs and clarification of goals visible in interactions
Alleviating lack of knowledge		
Limited additional information collected, organised and used	Additional information collected and organised but not used	Additional information collected, organised and used
Creating shared understanding		
Clear from data that assignment of knowledge object development was discussed in group meetings	Clear from data that knowledge objects were discussed in group meetings	Clear from data that development of knowledge objects was discussed in group meetings
Engaged in limited discussions creating shared understanding	Engaged in limited discussions creating shared understanding	Engaged in rich discussions creating shared understanding
Developed little understanding of principles, tools and task through deliberate effort	Developed some understanding of principles, tools and task through deliberate effort	Developed additional understanding of principles, tools and task through deliberate effort
Generative collaborative actions		
Knowledge objects were developed without incorporating feedback	Knowledge objects were developed with feedback.	Feedback was incorporated as knowledge object sections were developed
No agreed feedback mechanism	Agreed feedback mechanism	Agreed feedback mechanism
Individual contributions (labelled with team member names in production phase)	Individual contributions	Interdependent contributions
Regulative actions		
Projective		
Workflow designed by individual	Workflow designed collaboratively	Workflow designed collaboratively
Ad hoc knowledge object approval process	Structured knowledge object approval process	Structured knowledge object approval process involving multiple team members
Regulative		
Engaged in limited monitoring of shared knowledge object development and quality	Engaged in some monitoring of shared knowledge object development and quality	Engaged in shared monitoring of knowledge object development and quality
Relational		
Low level of relational interaction.	Moderate level of relational interaction.	High level of relational interaction.

5.7. Secondary data analysis

The purpose of this analysis is to understand whether we can confirm the conjectures set out in Section 5.6 through data triangulation. As it was not possible to validate the study results through student interviews or other methods, analysis of each group's synchronous group meetings notes and their articulated process models can provide another perspective on the collaboration from the participants' point of view. The analysis process uses the same thematic classification framework as that for the GitHub asynchronous data. As this analysis is intended as a modest validation mechanism, more data excerpts are included to provide additional evidence for classification and inference.

This section contains quantitative findings about the frequency and distribution of actions visible in each group's meeting notes within the whole cohort, and each team, that are classified as indicating epistemic or regulative agency, followed by qualitative findings about the way in which they approached their collaboration based on this data, represented visually by a word cloud of the top 15 categories of action for each team. Then results from a similar analysis of each group's process documents are presented. The following section 5.8 considers these findings together to evaluate the extent to which they support the conjectures made in the previous section.

5.7.1. Meeting notes

Teams A and C created seven meeting notes, and Team B six. A breakdown of the epistemic and regulative actions reported in the meeting notes follows at Table 30 below. However, quantitative data from these should be considered only a very general indication about activity as the coding frequency will not reflect the time spent on each topic or the depth of conversation.

Table 30: Actions reported in synchronous meeting notes by team and classification.

Team	Classification	(1) Creating awareness	(2) Alleviating lack of knowledge	(3) Creating shared understanding	(4) Generative collaborative actions	Epistemic Total	(5) Projective	(6) Regulative	Regulative Total	(7) Relational
A	A-Minutes 02-05-	1	2	2	3	8	3	6	9	0
A	A-Minutes 07-05-	1	1	1	2	5	3	2	5	0
A	A-Minutes 10-05-	0	0	0	0	0	3	3	6	0
A	A-Minutes 11-04-	0	1	0	0	1	6	1	7	0
A	A-Minutes 14-05	0	0	0	0	0	3	3	6	0
A	A-Minutes 18-04-	0	2	0	1	3	4	2	6	0
A	A-Minutes 21-05-	0	0	0	0	0	3	3	6	0
A Total		2	6	3	6	17	25	20	45	0
B	B-Meeting - 09.04	0	4	2	0	6	6	1	7	0
B	B-Meeting - 21.05	0	1	1	9	11	14	4	18	0
B	B-Meeting agend	0	3	1	6	10	6	7	13	0
B	B-Meeting agend	0	0	8	8	16	11	3	14	0
B	B-Meeting agend	0	3	2	5	10	6	10	16	0
B	B-Meeting-16.04.	0	2	6	4	12	15	3	18	0
B Total		0	13	20	32	65	58	28	86	0
C	C-Meeting - 14.05	0	0	1	5	6	7	2	9	0
C	C-Meeting 07 05	0	0	2	3	5	4	7	11	0
C	C-Meeting 16-04	0	0	7	3	10	5	6	11	0
C	C-Meeting_21.05	0	1	2	4	7	6	3	9	0
C	C-Meeting-0904	0	0	0	0	0	8	0	8	0
C	C-Meeting-1104	1	2	7	2	12	3	0	3	0
C	C-Meeting-30.04.	0	1	3	1	5	5	0	5	0
C Total		1	4	22	18	45	38	18	56	0
Total		3	23	45	56	127	121	66	187	0

5.7.1.1. Summaries of meetings by team

Team A meeting notes

A-Minutes 11-04-19

Team A's first meeting notes begin with the title of their project, "Automated Learning Management System Design" (A-Minutes 11-04-19, P. 1: 348), which is distinct from the title or description of the project task. We can see evidence of planning with the project broken down into two phases, with use case development first, followed by component and interaction models (A-Minutes 11-04-19, P. 1: 734), with the target for completion of the use cases the following week (A-Minutes 11-04-19, P. 1: 973) and the remaining models the week after (A-Minutes 11-04-19, P. 1: 1241). Each team member is assigned a reading to review "in contect of the assignment (A-Minutes 11-04-19, P. 2: 606)" and three are assigned a diagram to complete (A-Minutes 11-04-19, P. 2: 1299).

A-Minutes 18-04-19

The notes from Team A's next meeting indicate shared conversation around the assigned tasks, as they "Recap week 7 achievements" (A-Minutes 18-04-19, P. 1: 205) and "Review summarised readings" (A-Minutes 18-04-19, P. 1: 235). There is an activity header "Interpret Week 8 requirements" (A-Minutes 18-04-19, P. 1: 615) but no further information before the remainder of the notes discuss task allocation.

A-Minutes 02-05-19

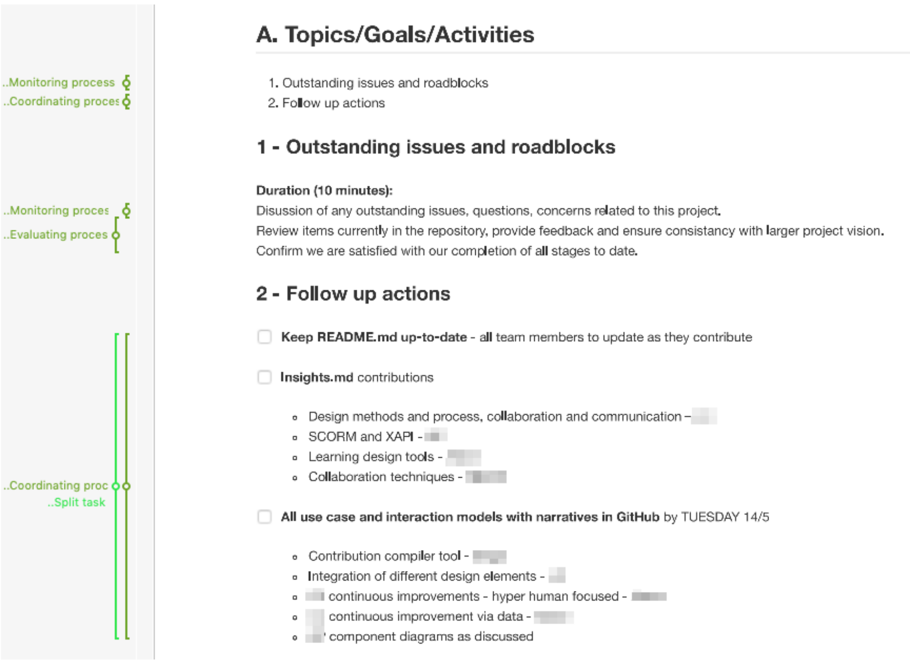
Review of task completion is the focus of the meeting of 02.04, with the first agenda item "Disussion of any outstanding issues, questions, concerns related to this project." (A-Minutes 02-05-19, P. 1: 427), followed by "Review items currently in the repository, provide feedback and ensure consistancy with larger project vision." (A-Minutes 02-05-19, P. 1: 566). The notes show that the team engage in a review process around two components of their design based on prompts from the instructor, noting the need for theoretical insights around "Social design: readings?" (A-Minutes 02-05-19, P. 2: 424) as well as using "what we learned about LD notations, and UML" (A-Minutes 02-05-19, P. 2: 136) as well as negotiating ideas around learning analytics and the role of human and automated planning and critique systems(A-Minutes 02-05-19, P. 2: 184). This meeting included a time for "Practising design critique" (A-Minutes 02-05-19, P. 2: 1167), with unassigned dot points to "Gather more information about DC (A-Minutes 02-05-19, P. 2: 1566), and "Create use stories/use cases for the processes" (A-Minutes 02-05-19, P. 2: 1600) before the remainder of the notes closes with task allocation.

A-Minutes 07-05-19

Other than the 'Missing pieces from stage 1' and the 'Practising design critique' section, and a minor edit to the text in the follow up actions regarding the *README.md* (A-Minutes 07-05-19, P. 1: 1394) this is a direct copy and paste from the previous meeting notes.

A-Minutes 10-05-19

As shown at Figure 34 below, the meeting notes contain only the object monitoring and task assignment items. They have minor modifications from the previous weeks, for example, instead of "AI learning design environments (A-Minutes 07-05-19, P. 2: 13)", in this week's notes [A1]'s *Insights.md* contribution task is "Design methods and process, collaboration and communication" (A-Minutes 10-05-19, P. 1: 668).



A. Topics/Goals/Activities

1. Outstanding issues and roadblocks
2. Follow up actions

1 - Outstanding issues and roadblocks

Duration (10 minutes):
Dissusion of any outstanding issues, questions, concerns related to this project.
Review items currently in the repository, provide feedback and ensure consistancy with larger project vision.
Confirm we are satisfied with our completion of all stages to date.

2 - Follow up actions

- [ ] **Keep README.md up-to-date** - all team members to update as they contribute
- [ ] **Insights.md** contributions
  - Design methods and process, collaboration and communication – [redacted]
  - SCORM and XAPI - [redacted]
  - Learning design tools - [redacted]
  - Collaboration techniques - [redacted]
- [ ] **All use case and interaction models with narratives in GitHub** by TUESDAY 14/5
  - Contribution compiler tool - [redacted]
  - Integration of different design elements - [redacted]
  - [redacted] continuous improvements - hyper human focused - [redacted]
  - [redacted] continuous improvement via data - [redacted]
  - [redacted] component diagrams as discussed

Figure 34: Excerpt from Team A meeting notes from 10.05 showing the points are related to outstanding Issues and follow up actions (Team A Meeting Minutes\A-Minutes 10-05-19: 1: 17 - 1: 1120).

A-Minutes 14-05-19

The notes from this meeting are a direct copy and paste from the previous meeting.

A-Minutes 21-05-19

Team A's notes from this meeting include only the "Review items…" and "Confirm we are satisfied…" items from the preceding weeks, and the assignment of presentation roles. There is a note "Next meeting: 5pm Friday 24/5/19", but no associated documentation in the repo.

Summary of Team A

The dominant activity reported in Team A's meeting notes is summarised in Figure 35 below.

Figure 35: Word cloud representing the top 15 classifications within Team A's meeting notes with size indicating coding frequency and colour only for visual differentiation.

Team B meeting notes

B-Meeting - 09.04.19

As well as some task-focused items, the notes recorded a discussion about definitions of different kinds of technological platforms, for example, a 2d platform is a phone or iPad, and 3d might be a VR headset, indicating a blend of epistemic and regulative interactions. From the item “Come up with graphical use cases to be done by next week - due next Tuesday” (B-Meeting - 09.04.19, P. 1: 1147), on the surface it appears as if the knowledge objects were constructed individually after this meeting.

B-Meeting-16.04.19

The notes from the second group meeting included the agenda, which contained a directive from the meeting facilitator reproduced at Figure 36 in which the goal of the collaboration might appear to be framed as to “update the required doucuments”.

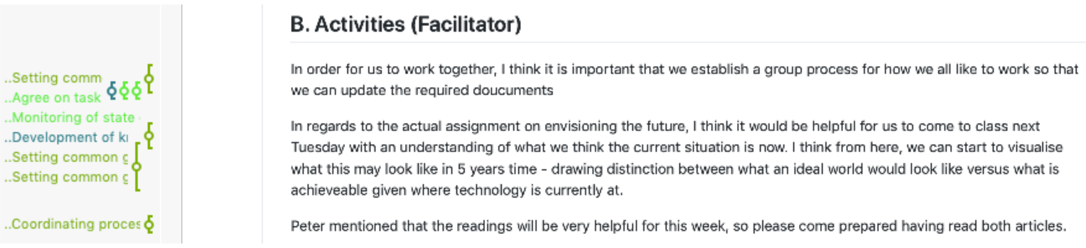


Figure 36: Excerpt from Team B meeting notes from 16.04.2019 (Team B Meeting Minutes\B-Meeting-16.04.19: 1: 902 - 1: 1486).

These meeting notes made it clear that Team B had an agreed task management process: “(Formulate action items as issues (connected to milestones) and link to these using their GitHib.)”(B-Meeting-16.04.19, P. 2: 1177), and also that the task was split between team members, with each team member being assigned a specific diagram or document to work on by a set deadline. The meeting notes concluded with a link to a document shared by a team member with a note “I suggest we discuss this in more detail at our next meeting.” (B-Meeting-16.04.19, P. 3: 1238) but no record of whether the discussion occurred.

B-Meeting agenda 30.04.19

Meeting notes from 30.04 confirm that team members are completing tasks individually within a shared understanding of the project with the comment “I'd like to catch up on individual tasks completed and discuss the overall scope of the task as we currently understand it.” (B-Meeting agenda 30.04.19, P. 1: 764). The items are generally focused around coordinating the collaborative process, but there are two ‘discuss’ items, both carried forward from the previous meeting. There is evidence of epistemic engagement, with an instruction to the team to “Look at design critiques in general” (B-Meeting agenda 30.04.19, P. 2: 1520) and their application at scale, to contribute a critique of their *Interactions.md* model in response to an instructor-initiated task.

B-Meeting agenda 07.05.19

In the meeting of 07.05, in addition to a review of task progress and assignment of tasks for the following week, the team conducted two discussions: after the design critique, “It was proposed that we include an immersive experience” (B-Meeting agenda 07.05.19, P. 1: 1044) and “we need more of a link to the pedagogical underpinning of our LDE.” (B-Meeting agenda 07.05.19, P. 1: 1221); and in relation to the viability of personalised learning paths for required learning outcomes “A successful personalised learning plan would be reliant on strong formative and diagnostic assessment along the pathway.” (B-Meeting agenda 07.05.19, P. 1: 1734).

B-Meeting agenda 14.05.19

In the week of 07.05s week’s meeting there is also a record of a substantial discussion in response to an optional instructor task to extend their LDE by smart handing of data from learners. The team decides instead to continue with what they have already developed, with the remainder of the notes around coordination to “clean up” (B-Meeting agenda 14.05.19, P. 1: 1419; P. 1: 2321; P. 2: 618; P. 2: 907) the repo and “look for gaps that need to be filled” (B-Meeting agenda 14.05.19, P. 1: 2373; P. 2: 1204). There is a decision to “Revise use case to focus on the teacher” (B-Meeting agenda 14.05.19, P. 1: 2274), but not an associated task, and a task “Improve by clarifying teacher role and how data will be used” (B-Meeting agenda 14.05.19, P. 2: 301), indication a monitoring of the object quality.

B-Meeting - 21.05.19

In the last meeting before task submission it is not surprising that much of the meeting focus was on revising knowledge object drafts. The team engaged in a conversation around the ‘Wow Factor’ of their design, structuring their knowledge in order to add it to a summary document in preparation for the following week’s presentation. Tasks for the intervening week, and the presentation, were individually assigned.

Summary of Team B

The dominant activity reported in Team B’s meeting notes is summarised in Figure 37.

Figure 37: Word cloud representing the top 15 classifications within Team B's meeting notes with size indicating coding frequency and colour only for visual differentiation.

Team C meeting notes

C-Meeting-0904

Team C's first meeting focused on understanding the collaboration and task framework, agreeing on a facilitation roster and assigning specific areas of the repo to review as well as "Everyone to review the Roles and Responsibilities link" (C-Meeting-0904, P. 2: 285). The meeting also described an epistemic aim, with "Everyone start brainstorming ideas for the project and do the task for next week <link removed> Think of a use case and a high level conceptual design - what can designers use to make their work easier, etc. What will this look like in the future? Automated?" (C-Meeting-0904, P. 2: 447)".

C-Meeting-1104

The notes from this meeting show Team C spent time discussing the different contents of their GitHub repo and determining a workflow, deciding "Always to a Pull Request and the always assign the Knowledge Manager and Facilitator to approve it and pull it." (C-Meeting-1104, P. 2: 1293). The main body of the notes is concerned with "Brainstorming on this week's task" (C-Meeting-1104, P. 2: 1556), a series of dot points that loosely describe some features and elements that should be considered in their design, for example, "Need a model that has a balance between the automation and creativity" (C-Meeting-1104, P. 2: 2590), and "Use case models how the actors flow through the model" (C-Meeting-1104, P. 2: 2767).

C-Meeting 16-04

Team C spent this meeting focused on their use case modelling and providing feedback on the three models developed so far, deciding to "keep thinking about possible future scenarios but stick with 2 models." (C-Meeting 16-04, P. 2: 292). They agreed that their current way of approving changes to the master branch was “Limiting” (C-Meeting 16-04, P. 2: 1840) but they would “Stick with the same process” (C-Meeting 16-04, P. 2: 1852). As the Easter break was coming up and completing their tasks beforehand was unlikely, they followed their preference for using Issues for discussion (C-Meeting 16-04, P. 2: 1468), opening a new Issue for “chatting to see whether a meeting next week is required.” (C-Meeting 16-04, P. 2: 2035).

C-Meeting-30.04

The meeting notes from 30.04 indicate the team continued to elaborate on the use case models and their integration with other models in development, with conversations around “how many models (e.g. interactions & component models) are we meant to have per use case?” (C-Meeting-30.04.pdf, P. 1: 435) and whether the interactions model “may need to align with [C2’s] latest model” (C-Meeting-30.04.pdf, P. 1: 570). The team agree that various individuals will develop and propose diagrams based on the existing use cases, and that “[C4] will adjust her interactions diagram to reflect [C2’s] new user scenario model … [and] [C3] will adjust her component diagram based on the feedback aroused in the group’s meeting (30.04.19)” (C-Meeting-30.04.pdf, P. 2: 565). Updates to the team’s process documents are also assigned to each team member.

C-Meeting 07-05

In these meeting notes we see the team has overcome the limitations of the previous approval process and has moved to “Only 2 voters + the creator of the PR (3 in total) for merging pull requests instead of 5.” (C-Meeting 07-05, P. 1: 997), with small changes articulated with parent use cases committed directly to master branch (C-Meeting 07-05, P. 1: 1208). The notes also indicate a discussion around clarifying the meaning of PE (Personalisation Engine), xAPI (Experience Application Programming Interface) and LA (Learning Analytics), their characteristics, and the interactions between course designer and “the PE not the LA.” (C-Meeting 07-05, P. 1: 974). The conversations around PE, LA and xAPI all feed into a task to update the use case parent model, and as well as process-related updates there is a task to change the interaction diagram in response to the instructor design critique task and a new glossary document to be created.

C-Meeting - 14.05

These meeting notes show that Team C has begun to refine their set of models, with agreement on terminology, interactions, role of the system design and location of the glossary taking up the first Agenda item (C-Meeting - 14.05, P. 1: 150), closely followed by a logic check across all the team's diagrams (C-Meeting - 14.05, P. 1: 485). They reach agreement on the first item, and assign action items to all team members to enact these changes. The comment "Insights: a lot of feedback is from people going into detail of models. Narrative is being built weekly. Cyclical process. Needs to be monitored and updated as required." (C-Meeting - 14.05, P. 2: 527) indicates a high level of feedback that is incorporated into knowledge object development, and conscious monitoring of status and quality.

C-Meeting_21.05

In their final meeting before the task submission, Team C were addressing issues with merge conflicts which they tried to resolve by "merging to another team members branch" (C-Meeting_21.05, P. 1: 1138). While the team are concerned with reviewing their knowledge object s and assigning roles for the final presentation, they are also asking for feedback on "major changes" (C-Meeting_21.05, P. 1: 1341) to a components diagram and still negotiating ideas around "an interactions diagram as AI will be the focus" (C-Meeting_21.05, P. 2: 168) and another contribution with a "focus on learning analytics" (C-Meeting_21.05, P. 2: 316). They agree that "Corresponding components diagram will only be done if anyone has the time." (C-Meeting_21.05, P. 2: 389) but are undecided about "the meaning of the use case" (C-Meeting_21.05, P. 2: 706) for the recent Internet of Things (IOT) use case and corresponding components diagrams.

Summary of Team C

The dominant activity reported in Team C's meeting notes is summarised in Figure 38 below.

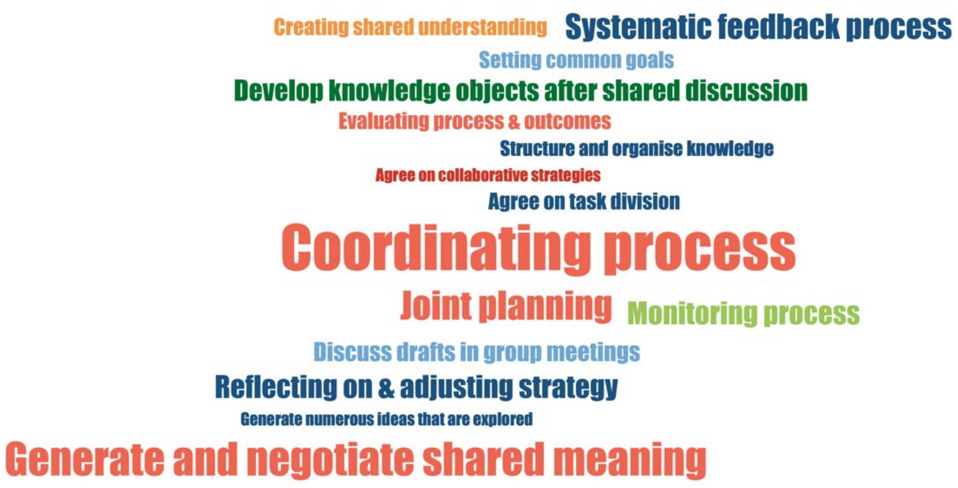


Figure 38: Word cloud representing the top 15 classifications within Team C's meeting notes with size indicating coding frequency and colour only for visual differentiation.

5.7.2. Summary of meeting notes

Meeting notes for all teams reflect their purpose as a space for coordinating the teams' project work; planning, evaluating and adjusting their process. Within the limitations of the data, we can also see emphasis on different aspects of both epistemic and regulative dimensions. Team A's meeting notes reflect a task-driven approach with less discussion around generating and sharing ideas, and little evidence of collaborative knowledge object construction and feedback processes. Team B's notes reflect time spent on idea generation and negotiation, and more evidence of collaborative knowledge object construction and feedback processes. Team C's notes reflect a focus on idea generation, with evidence of collaborative knowledge object construction and a stronger indication of a systematic feedback process.

5.7.3. Process documents

5.7.3.1. Insights.md

The *Insights.md* document was used completely differently between teams.

Team A

Team A added several unrelated sections to their *Contributing.md* document, excerpted from "a paper I have compiled on Learning Design Tools." (A-Insights: 1: 2460 - 1: 2544). They include links to their reading summaries, design critique template and workflow document. They describe an "evolving" (A-Insights: 1: 543 - 1: 550) collaborative process, and "a routine for distributing weekly tasks, conducting meetings, providing feedback and ensuring we progress at the necessary rate through this project." (A-Insights: 1: 1506 - 1: 1657). The *Insights.md* document describes discussing drafts in team meetings (A-Insights: 1: 2198 - 1: 2306).

Team B

Team B described their process as "both delegative and collaborative" (B-Insights: 1: 190 - 1: 250), in which they "sought out the feedback of others and contributed to shared work." (B-Insights: 1: 787 - 1: 852). There are also indications of this combination in the insights document, with several paragraphs written in the first person plural "we", but also an illustration of an individualised, task-driven approach at "I found that our collaboration and communication was hindered at the beginning of the group project by a lack of understanding around the requirements of the task. Over the first couple of meetings, together with further information in lectures, I feel this was no longer an issue. It made me reflect that to have effective collaboration and communication there needs to be a clearly defined task so that each member knows how they can best contribute. (B-Insights: 1: 890 - 1: 1345). The Insights.md document describes discussing "big picture topics" in Issues, and focusing on "more pressing issues during meetings" (B-Insights: 1: 1347 - 1: 1773).

Team C

Team C conducted a traditional reflection with weekly timeline, describing lessons learned around the process and the actions they took to improve the way they worked and celebrating their progress. For example, the comment that it is a "good sign that we are no longer in a confused state as a group, but are now able to look at the bigger picture of the project. We are at the point where we are having small discussions about where to place arrows and what words to use instead of how to create models and use Github. It feels like the group and the project have moved to a new stage" (C-Insights: 1: 5377 - 1: 5756). Discussions around the team's work in meetings are mentioned in the narrative, including the way in which the team managed different interpretations of the terms in their 'parent' model by constructing a definitions document and ensuring "everyone's understanding of the parent model, flow and logic is the same" (C-Insights: 1: 4319 - 1: 4390)"

5.7.3.2. Contributing.md

Team A

Team A made only four changes to the provided template: setting out different days for meetings, linking to the additional document prepared by one team member, linking to meeting notes folder and the workflow diagram.

Team B

While the processes section of the document is unchanged from the template, Team B set out a weekly workflow that indicated agreement on collaborative strategies, discussion of drafts in meetings, setting common goals, and monitoring work in progress. For example, Tuesday activities are listed as "We watch out for new issues posted by [instructor] and [researcher]. Add new issues to the agenda. Meet for an hour. If there is not enough time, reschedule the meeting to Wednesday morning." (B-contributing: 1: 1081 - 1: 1266).

Team C

Team C made substantial changes to the *Contributing.md* document to reflect their "democratic and constructive" (C-contributing: 1: 894 - 1: 903) (differentiated from the template's "social and constructive") aim for collaboration. The weekly workflow was detailed not only about the document approval and merge processes, but also meeting to “determine goals and tasks for the week.” (C-contributing: 1: 1147 - 1: 1247), “discuss and critique models/items within the pull request until a concensus is reached” (C-contributing: 1: 2092 - 1: 2224), and their goal to “collaborate openly and honestly, building on and valuing each person's contributions, opinions and areas of expertise.” (C-contributing: 1: 740 - 1: 872).

5.7.3.3. Roster.md

Each team constructed a *Roster.md* document from the template that included a Facilitator and Knowledge Manager role each week, which was often but not always followed.

5.7.3.4. Processes.md

Each team constructed a *Processes.md* document based on one of the supplied templates. All documents included a structured discussion and approval process involving multiple team members.

Team A constructed two process models, a “holistic” overall process (A-Processes: 1: 218) and a weekly workflow (A-Processes: 3: 541).

Team B constructed a single model of their general approach (B-Processes: 1: 223).

Team C constructed two process models, a weekly workflow (C-Processes: 1: 642) and a model specific to their Pull Request discussion and approval process (C-Processes: 2: 1321).

5.8. Level of support for conjectures from meeting notes and process documents

The meeting notes and process documents provide varied levels of support for the conjectures which emerged from the analysis of the GitHub asynchronous interaction data. Each table below is a conjecture about a characteristic of collaborative process present in one or more of the teams in this study. The data from the meeting notes has been considered in relation to each of these conjectures, and the level to which the data might be said to support each conjecture suggested, with examples from the text cited as a basis for that suggestion. These findings are considered further in Section 6.1.2.

5.8.1. Epistemic actions

Creating awareness		
A	B	C
Identification of needs and clarification of goals not visible in interactions	Identification of needs and clarification of goals not visible in interactions	Identification of needs and clarification of goals visible in interactions
meeting notes do not support	meeting notes partially support	meeting notes partially support

In Team A's meeting notes we can see their goal identification early with a clear title for their project "Automated Learning Management System Design" (A-Minutes 11-04-19, P. 1: 348) and focus on "Use case diagrams completed & Narative to support the description of the diagrams, Summary of readings, relevance to Automated Learning Management System Design. ([A4], create diagram for producing environments -> System that hosts a series of courses). (A-Minutes 11-04-19, P. 1: 982). The need for further theoretical foundation was articulated in the first week, with a follow up item for "Each team member to review reading in contect of the assignment. Take notes/draft models to help develop the basis of our scenarios. *How do the below readings relate to the project? Take notes/draft models on current/future scenarios"* (A-Minutes 11-04-19, P. 2: 571).

There are multiple mentions of the task deadlines in Team B's meeting notes and the team member assigned to create the diagram or update the document but little information on the broader goals of the project or the theoretical understandings that might inform them. The notes do show that the task as a whole was discussed both at the beginning of the project: "However, we discussed what the scope of the whole task is- not needing to be too technical in our detail, but a big picture concept level as a meta designer." (B-Meeting-16.04.19, P. 2: 1966); and toward the end in response to the optional instructor extension task, design critique and knowledge exchange where the team debate "Strengthen current work or look at the additional aspect??" (B-Meeting agenda 14.05.19, P. 1: 886).

The meeting notes indicate that Team C did discuss identifying their needs and goals, with the group reviewing the "Roles and Responsibilities link" (C-Meeting-0904, P. 2: 308), and "brainstorming ideas for the project" (C-Meeting-0904, P. 2: 462), considering "Think of a use case and a high level conceptual design - what can designers use to make their work easier, etc. (C-Meeting-0904, P. 2: 616). The notes do not show the team specifying particular theoretical directions to research, rather "All of us will review research papers and/or online examples and post findings or ideas. (C-Meeting-30.04, P. 2: 1083). Team C also "Did not get around to addressing the optional smart functionality diagrams", "but still interested in doing it" (C-Meeting_21.05, P. 2: 36), with a new interactions diagram with a focus on learning analytics planned for the last week prior to the task deadline (C-Meeting_21.05, P. 2: 145).

Alleviating lack of knowledge		
A	B	C
Limited additional information collected, organised and used	Additional information collected and organised but not used	Additional information collected, organised and used
meeting notes partially support	meeting notes partially support	meeting notes do not support

Team A's meeting notes show that readings are assigned to individual team members for review (A-Minutes 18-04-19, P. 1: 249), and in the following meeting there are mentions of "readings" (A-Minutes 02-05-19, P. 2: 424), "what we learned" (A-Minutes 02-05-19, P. 2: 136), and "gather more information" (A-Minutes 02-05-19, P. 2: 1566).

The meeting notes from Team B indicate meetings were substantially spent coordinating process, but there are also mentions of "discussing" a shared link (B-Meeting-16.04.19, P. 3: 1238), looking at design critiques (B-Meeting agenda 30.04.19, P. 2: 1520), finding "more of a link" to pedagogies (B-Meeting agenda 07.05.19, P. 1: 1221), and a conversation about whether to extend their design to incorporate more 'Wow' factor (B-Meeting - 21.05.19: 2: 0 - 2: 1106).

There was little information in Team C's meeting notes about searches for additional information, with their focus on discussing their models and engaging in clarification around the various systems and elements.

Creating shared understanding		
A	B	C
Clear from data that assignment of knowledge object development was discussed in group meetings	Clear from data that knowledge objects were discussed in group meetings	Clear from data that development of knowledge objects was discussed in group meetings
meeting notes support	meeting notes support	meeting notes support

As we have seen, the main topic of Team A's meeting notes was the assignment of the development of knowledge objects. We have also seen that there was a recurring item on the agenda to review items in the repo and provide feedback, but no other information about that occurring. We do see the development of knowledge objects mentioned, for example, “In this phase, envision two future scenarios for online communities of instructional designers. This requires that you predict changes in the kind of tasks designers will have to work on in 4-5 years and changes to the work designers will do. Consider both an "achievable" solution and an "ideal" solution.” (A-Minutes 11-04-19, P. 1: 424), and “Develop either one or both of the scenarios you thought of before further Compare your design with the state of the art today and/or compare your design with a more idealistic or realistic vision of the future.” (A-Minutes 02-05-19, P. 1: 1259); these are the instructor scenarios which comprise the task.

It is clear from the meeting notes that the knowledge objects were discussed in Team B’s meetings, but it is more difficult to know what about them was discussed, for example “Comments fromo [B1] & [B5] about creating the components and interactions diagrams. Are there any outstanding questions or items to resolve?” (B-Meeting agenda 30.04.19, P. 1: 997). From the five-minute duration of the activity and the phrasing of the agenda item, it seems likely that the models were presented and discussed in the meeting, and feedback potentially provided but not what that feedback was or what that meant.

We have seen above that discussion of knowledge objects in team meetings was part of Team C’s agreed feedback mechanism and that it occurred on a regular basis. The meeting notes reflect this with items such as “Discuss the task for this week and [C3’s] model located in issues” (C-Meeting-1104, P. 1: 814), “Go through Use Case Model and discuss” (C-Meeting 16-04, P. 1: 618), “[C2] to discuss updates to use cases” (C-Meeting-30.04.pdf, P. 1: 205), “Check internal logic across the diagrams (C-Meeting - 14.05, P. 1: 526), and “Alignment and logic of models (C-Meeting_21.05, P. 1: 189)”.

Creating shared understanding		
A	B	C
Engaged in limited monitoring of shared knowledge object development and quality	Engaged in some monitoring of shared knowledge object development and quality	Engaged in shared monitoring of knowledge object development and quality
meeting notes support	meeting notes support	meeting notes support

Team A’s meeting notes focus on knowledge object completion, and as mentioned above, there is a continued agenda item to review, check for consistency and “Confirm we are satisfied with our completion” (A-Minutes 02-05-19, P. 1: 677). While a list of documents with team member names assigned to them is a consistent feature of each meeting’s notes, there is no indication of review status, consistency check, or quality assurance associated with them and the same documents appear for several weeks running.

Team B did monitor knowledge object development, with coordinating processes and planning the dominant content featuring in all instances of meeting notes. In the last meeting prior to task submission the team discussed in detail the status of their drafts, and in the meeting 30.04 the follow up action include some points that indicate the knowledge objects have been reviewed for quality as well as completion, for example, as shown at Figure 39 below.

- Focus 1: Social / Collaboration points (look at languages – UML, SCS?) - [redacted]
- Focus 2: Data collection (collects data on student's interaction with program – feeds into teacher dashboard). AI can organise data in usable way – user-friendly - [redacted]
- Focus 3: Dashboard – create dashboard (linked to Focus 2) [redacted]

Figure 39: Excerpt from Team B meeting notes from 30.04 indicating the team engaged in some monitoring of the quality of their use-case.md knowledge objects.

Team C also monitored knowledge object development, and their focus on quality can be seen in the detail that early development was reported on in the meeting notes, as shown at Figure 40 below, and then when the team finish "tweaking the parent use case model so that it better flows with the logic of the interaction diagrams" (C-Meeting 07-05, P. 1: 1101), and finally check the internal logic across all their models in relation to ""Parent" scenario and use case models" (C-Meeting - 14.05, P. 1: 486).

[redacted] will send text of the use case model to [redacted] and he will model it in PlantText. [redacted] will put it int he UseCase.md file and use a pull request and assign [redacted] who will edit it with the model and merge it. All other team members will then review and discuss at next meeting.

Figure 40: Excerpt from Team C's meeting notes from 11.04 discussing early model development.

The team also recorded the work needed to keep up to date with the different developments "Insights: a lot of feedback is from people going into detail of models. Narrative is being built weekly. Cyclical process. Needs to be monitored and updated as required." (C-Meeting - 14.05, P. 2: 527). Leading up to the task submission deadline, Team C also assigned specific team members to review particular models as well as "practice their part of the presentation!" (C-Meeting_21.05, P. 2: 1419).

Creating shared understanding		
A	B	C
Engaged in limited discussions creating shared understanding	Engaged in limited discussions creating shared understanding	Engaged in rich discussions creating shared understanding
meeting notes support	meeting notes support	meeting notes support

As we have seen above, Team A engaged in some discussion around a review of their design, but no further idea-based discussion after this, with all subsequent meeting notes focused on task allocation.

While the majority of Team B's meeting notes are task-oriented, it was possible to see some deliberate effort expended on generating ideas in one meeting where they consider whether to adopt the optional instructor task to extend their LDE by smart handing of data from learners. After weighing up their shared expertise and interests, and the work done so far, the team discuss the comparative benefit of doing more research on the data handling and the consequent changes to their repo. They decide instead to "Revise use case to focus on the teacher" (B-Meeting agenda 14.05.19, P. 1: 2274), with some continued discussion around the teacher- and student-centredness of the data handling in the following week, summarised as "We have a learner centred and teacher faciltated framework which distinguishes us from other groups." (B-Meeting - 21.05.19, P. 2: 421).

Team C's meetings contained conceptual as well as task-focused discussions based on the meeting notes, with the group "brainstorming ideas for the project" (C-Meeting-0904, P. 2: 462) in the first week, then in the following week "Brainstorming on this week's task" (C-Meeting-1104, P. 2: 1556) which scoped out the broad concepts for model types and the role of AI in a learning design system (C-Meeting-1104, P. 2: 1594). The team engaged in discussion offline, shown by "Prefered ways of discussing items: continue using Issues" (C-Meeting 16-04, P. 2: 1469), but also created shared understanding in meetings.

Creating shared understanding		
A	B	C
Developed little understanding of principles, tools and task through deliberate effort	Developed some understanding of principles, tools and task through deliberate effort	Developed additional understanding of principles, tools and task through deliberate effort
meeting notes partially support	meeting notes support	meeting notes support

Team A’s meeting notes revealed little about their engagement with the collaborative work, growing increasingly focused on task assignment over the course of the project. There are some clues as to the ideas they were considering in the allocation of topics, and they engaged in a design critique process in response to an instructor task where they are able to structure information in relation to the instructor prompts, drawing on “what we learned about LD notations, and UML” (A-Minutes 02-05-19, P. 2: 136) and noting the need for more information in regard to “Social design: readings?“ (A-Minutes 02-05-19, P. 2: 424). There is no further discussion in relation to ideas in the meeting notes for this team in this project. The team’s *Processes.md* document contains two well-formed models with some creative features which reflect the workflow described in the meeting notes (and they do not mention feedback except in one word in the associated narrative).

Team B did engage in some efforts to engage with the principles, tools and task in their group meetings, for example, in their first meeting they “define 2d/2.5d/3d platforms” (B-Meeting - 09.04.19, P. 1: 889), and in the second meeting the agenda stated “so please come prepared having read both articles.” (B-Meeting-16.04.19, P. 1: 1559) in relation to the set readings for the week. The team engaged in discussion around the ‘Wow Factor’ of their design and the direction of the project in two meetings prior to the task submission and there was an article shared in the team meeting notes around educational technology. The team’s *Processes.md* document contains a well-formed model which reflects the workflow described in the meeting notes.

Team C’s meeting notes also show efforts to develop their understanding of the different elements of the collaborative project. Early in the project they individually conducted a “Review and Feedback of Github pages” (C-Meeting-1104, P. 2: 577), and developed use cases which became the ‘parent’ models for the other types of models that the team designed. We can see they sought clarification from the instructor on whether the output from the previous triple task was to be incorporated (C-Meeting-1104, P. 2: 1533), the number of use cases required (C-Meeting-30.04, P. 1: 244), and whether AI could be an actor in a use case diagram (C-Meeting_21.05, P. 2: 220). The team's *Processes.md* document contains two well-formed models with some creative features which accurately reflect the modified workflow described in the meeting notes.

Generative collaborative actions		
A	B	C
Knowledge objects were developed without incorporating feedback	Knowledge objects were developed with feedback.	Feedback was incorporated as knowledge object sections were developed
meeting notes support	meeting notes partially support	meeting notes support

We have seen above that Team A that the meeting notes do not show an agreed or other feedback process in operation, although one is mentioned in text, nor do they show knowledge objects discussed in meetings, nor knowledge object development incorporating feedback from others.

It is not clear from Team B's meeting notes the role feedback played in model development, although we have seen above that there are three occasions in the meeting notes on 30.04 where feedback is mentioned, and another instance where it was potentially provided. However, we have also seen that on 14.05 discussion on the direction of the project in response to the instructor extension task does result in the team deciding to focus on the teacher, and consolidation of the work already done.

Team C's meeting notes indicate that feedback was incorporated into knowledge objects during development. For example, when three use case models were presented to the team in their meeting on 16-04, the team decided to "keep thinking about possible future scenarios but stick with 2 models" (C-Meeting 16-04, P. 2: 292), with a follow up action to review one of the models "where people will be replaced entirely by AI" (C-Meeting 16-04, P. 2: 618). After the use cases were updated, the team discussed how the interactions model "may need to align with [C2's] latest model" (C-Meeting-30.04.pdf, P. 1: 570), and another team member "will adjust her component diagram based on the feedback aroused in the group's meeting" (C-Meeting-30.04.pdf, P. 2: 667).

Generative collaborative actions		
A	B	C
No agreed feedback mechanism	Agreed feedback mechanism	Agreed feedback mechanism
meeting notes support	meeting notes partially support	meeting notes support

As discussed above, Team A’s meeting notes and *Processes.md* mention feedback but there is no discussion on how or when it occurs and no evidence of it occurring in relation to the knowledge objects.

There are three mentions in Team B’s meeting notes from the 30.04 around feedback on the use case diagram (B-Meeting agenda 30.04.19, P. 1: 1180; P. 1: 480; P. 2: 2025), but no further insight into an agreed feedback mechanism.

As well as the agreed process for processing Pull Requests discussed above, there is specific mention that Team C “review all the pull requests at the meeting.” (C-Meeting 16-04, P. 2: 1617).

Generative collaborative actions		
A	B	C
Individual contributions (labelled with team member names in production phase)	Individual contributions	Interdependent contributions
meeting notes support	meeting notes support	meeting notes support

Team A’s meeting notes indicate that work was assigned and completed individually. There is a repeated agenda item that includes the phrase “Review items currently in the repository, provide feedback and ensure consistancy with larger project vision.” (A-Minutes 02-05-19, P. 1: 566 and subsequent weeks) which may or may not mean that individual team members were meant to check that their work integrated coherently with that of others.

Team B’s meeting notes indicate that work was completed individually, in two-week blocks with two people assigned to a two-week block but working independently.

The meeting notes from Team C also show task division, as well as shared feedback and decision-making. Modelling, feedback and update of process documents were shared between the team members.

5.8.2. Regulative actions

Projective		
A	B	C
Workflow designed by individual	Workflow designed collaboratively	Workflow designed collaboratively
meeting notes support	meeting notes support	meeting notes support

Team A's notes do not indicate that their workflow was discussed before or after "Weekly workflow diagram" (A-Minutes 11-04-19, P. 2: 1321) was assigned for development at the first group meeting.

Meeting notes show that Team B had an agreed task management process: "(Formulate action items as issues (connected to milestones) and link to these using their GitHib.)" (B-Meeting-16.04.19, P. 2: 1177), and that this was discussed in a team meeting: "Also discussed team work flow- see updated contributing & processes diagram." (B-Meeting-16.04.19, P. 2: 2964).

Team C also designed their workflow collaboratively, agreeing on their facilitation roster at their first meeting, and revising it to make it more flexible for small changes to individual models, deciding "Only huge changes will be put in Pull Requests." (C-Meeting 07-05, P. 1: 1350).

Projective		
A	B	C
Ad hoc knowledge object approval process	Structured knowledge object approval process	Structured knowledge object approval process involving multiple team members
meeting notes and process document partially support	meeting notes and process document support	meeting notes and process document support

It is not clear from the meeting notes whether Team A had a structured knowledge object approval process. The *Processes.md* document contains a node "Meeting space to discuss weekly progress and reveiw draft completed tasks prior to approval (A-Processes, P. 2: 957)", and there is a repeating agenda item "Review items currently in the repository, provide feedback and ensure consistancy with larger project vision." (A-Minutes 02-05-19, P. 1: 564; A-Minutes 07-05-19, P. 1: 414; A-Minutes 10-05-19, P. 1: 364; A-Minutes 14-05-19, P. 1: 363; A-Minutes 21-05-19, P. 1: 291) but no further elaboration in the documents.

Both the *Processes.md* document and the meeting notes indicate a structured knowledge approval process for Team B.

Team C also developed a structured approval process, visible in the *Processes.md* document and the meeting notes, and revised to reduce the number of approvers from five to three (C-Meeting 07-05, P. 1: 1034) for Pull Requests around half way through the project, bypassing the Pull Request process altogether "When we change our individual models we will Commit directly if changes are small and articulated with parent use case/interaction diagrams." (C-Meeting 07-05, P. 1: 1208).

Regulative		
A	B	C
Engaged in limited monitoring of shared knowledge object development and quality	Engaged in some monitoring of shared knowledge object development and quality	Engaged in shared monitoring of knowledge object development and quality
meeting notes support	meeting notes support	meeting notes support

Team A's meeting notes focus on knowledge object completion, and as mentioned above, there is a continued agenda item to review, check for consistency and "Confirm we are satisfied with our completion" (A-Minutes 02-05-19, P. 1: 677). While a list of documents with team member names assigned to them is a consistent feature of each meeting's notes, there is no indication of review status, consistency check, or quality assurance associated with them and the same documents appear for several weeks running.

Team B did monitor knowledge object development, with coordinating processes and planning the dominant content featuring in all instances of meeting notes. In the last meeting prior to task submission the team discussed in detail the status of their drafts, and in the meeting 30.04 the follow up action include some points that indicate the knowledge objects have been reviewed for quality as well as completion.

Team C also monitored knowledge object development, and their focus on quality can be seen in the detail that early development was reported on in the meeting notes, when the team finish "tweaking the parent use case model so that it better flows with the logic of the interaction diagrams" (C-Meeting 07-05, P. 1: 1101), and then finally check the internal logic across all their models in relation to ""Parent" scenario and use case models" (C-Meeting -14.05, P. 1: 486).

The team also recorded the work needed to keep up to date with the different developments "Insights: a lot of feedback is from people going into detail of models. Narrative is being built weekly. Cyclical process. Needs to be monitored and updated as required." (C-Meeting - 14.05, P. 2: 527). Leading up to the task submission deadline, Team C also assigned specific to review particular models as well as "practice their part of the presentation! (C-Meeting_21.05, P. 2: 1419).

5.9. Revised conjectures about the collaborative characteristics of each team

The indication of the level of support provided for the initial conjectures after triangulation with analysis of meeting notes and process documents is at Table 31 below. Black text on a white cell background indicate full support, on light grey background indicates partial support, and grey text on a white background indicates no support. Of the 33 conjectures, two were not supported by the additional qualitative data analysis, eight were partially supported, and 23 were supported. This suggests that the GitHub data can to some extent be relied on to understand group collaborative behaviours, and can provide insight into relational presence that meeting records and process data might not.

Table 31: Revised conjectures about the characteristics of the collaboration process by group after comparison of the findings from the secondary analysis.

Team A	B	C
Epistemic Actions		
Creating awareness		
Identification of needs and clarification of goals not visible in interactions	Identification of needs and clarification of goals not visible in interactions	Identification of needs and clarification of goals visible in interactions
Alleviating lack of knowledge		
Limited additional information collected, organised and used	Additional information collected and organised but not used	Additional information collected, organised and used
Creating shared understanding		
Clear from data that assignment of knowledge object development was discussed in group meetings	Clear from data that knowledge objects were discussed in group meetings	Clear from data that development of knowledge objects was discussed in group meetings
Engaged in limited discussions creating shared understanding	Engaged in limited discussions creating shared understanding	Engaged in rich discussions creating shared understanding
Developed little understanding of principles, tools and task through deliberate effort	Developed some understanding of principles, tools and task through deliberate effort	Developed additional understanding of principles, tools and task through deliberate effort
Generative collaborative actions		
Knowledge objects were developed without incorporating feedback	Knowledge objects were developed with feedback.	Feedback was incorporated as knowledge object sections were developed
No agreed feedback mechanism	Agreed feedback mechanism	Agreed feedback mechanism
Individual contributions (labelled with team member names in production phase)	Individual contributions	Interdependent contributions
Regulative actions		
Projective		
Workflow designed by individual	Workflow designed collaboratively	Workflow designed collaboratively
Ad hoc knowledge object approval process	Structured knowledge object approval process	Structured knowledge object approval process involving multiple team members
Regulative		
Engaged in limited monitoring of shared knowledge object development and quality	Engaged in some monitoring of shared knowledge object development and quality	Engaged in shared monitoring of knowledge object development and quality
Relational		
No meeting or process data.	No meeting or process data.	No meeting or process data.

The results of Stage 2 follow in the next section.

5.10.Trajectory analysis of joint activity and knowledge object advancement

This section reports the association of interactions and actions with the production of knowledge objects for the assessed project task over the course of the teaching session. The task involved iteratively developing system models for learning design environments. Interactions involving more than one team member that led to advancement of the knowledge object toward completion are considered productive interactions and indicative of shared epistemic agency.

The following sections present both qualitative findings and quantitative analysis of knowledge object advancements and productive interactions for each team for every artefact they created for the assessable task. While the documents in the charts are listed alphabetically, the narrative proceeds in the order that the documents were developed.

To present a temporal view of the data, each chart is organised from left to right in teaching weeks. Presentation of data differs slightly for each chart type.

5.10.1. Overview of trajectory analysis results

The GitHub data shows the level and type of interaction by team/group at individual, group and knowledge object level. While identifying substantive developments as connected with specific productive interactions can be challenging because of each group's particular way of using the environmental tools and workflows for collaborative model construction, the data does reveal the level of engagement with knowledge objects over time and the volume and frequency of interactions that lead to concrete knowledge object advancement. This allows an observation of the emergence of shared epistemic agency associated with the levels of productive interactions and knowledge object advancement over the course of the project. The data also shows interactions that did not result in knowledge object advancement, and whether work on intermediate knowledge objects contributed to the teams' final product.

Figure 41 below provides a visual representation of two dimensions of results for the three teams over the project Weeks 7-12. The bar graph shows the number of weekly interactions that either led to or directly indicated knowledge object advancement, classified by knowledge object and GitHub affordance. The line graph shows the number of weekly interactions that did not result in progress in the team project. These are reported in more detail below.

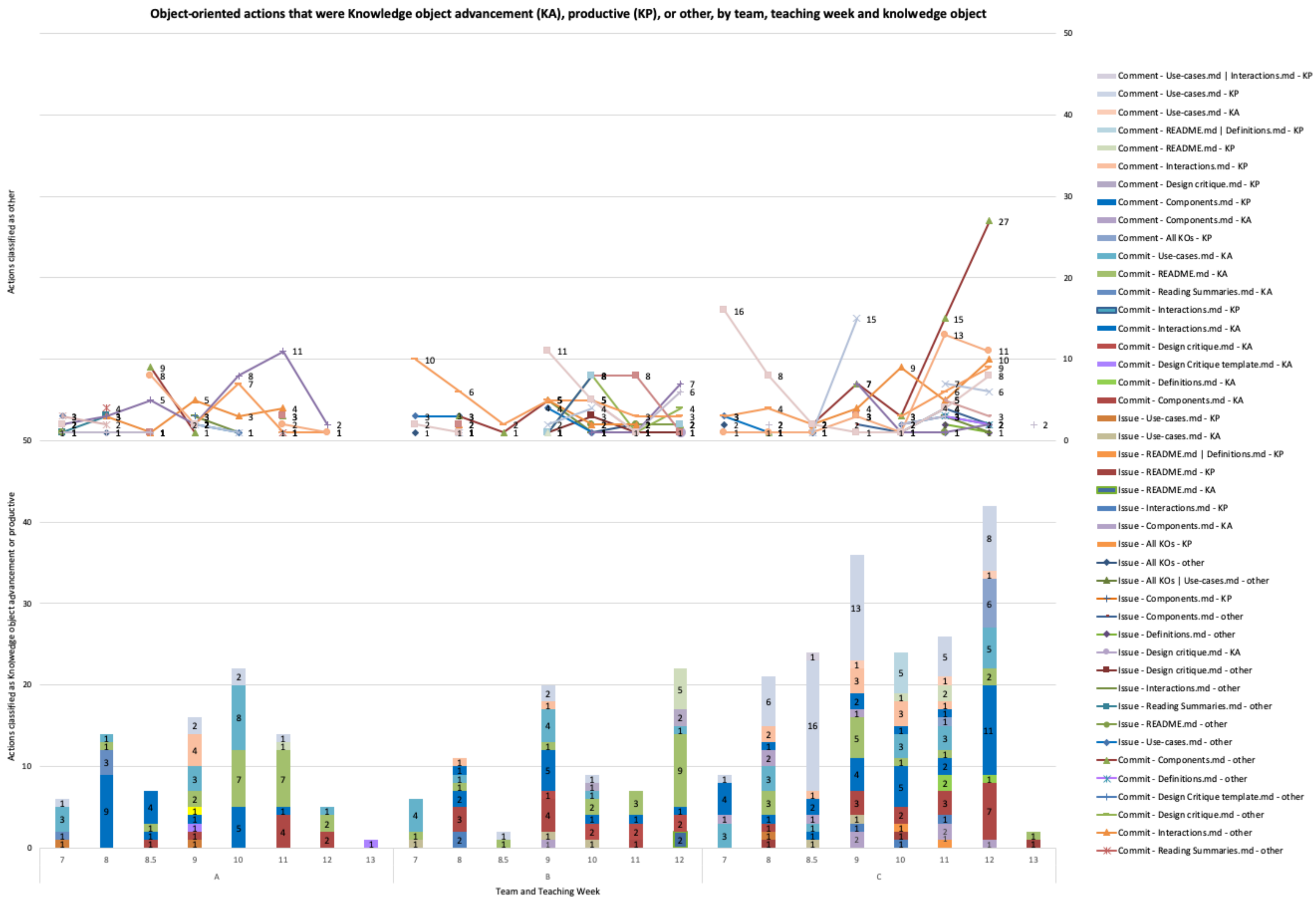


Figure 41: Comment, Commit and Issue knowledge object-related actions and interactions by team and week.

All teams created intermediate objects: A *Reading summaries.md* which weren't visibly incorporated into their knowledge objects, B *Design critique.md* which wasn't visibly incorporated into their knowledge objects, C *Definitions.md* which was a detailed explanation of the technical and conceptual underpinnings of their system design and was linked in a meaningful way from their *README*. Table 32 shows the number of actions and interactions for all knowledge objects by productivity and team below.

Table 32: All types of comment, Commit and Issue knowledge object-related actions and interactions by knowledge object, productivity and team.

	Team and activity												
	⊟ A			A Total	⊟ B			B Total	⊟ C			C Total	Grand Total
Knowledge object	KA	KP	other		KA	KP	other		KA	KP	other		
⊟ All KOs			**6**	**6**			**23**	**23**		**8**	**11**	**19**	**48**
Comment			4	4			19	19		7	7	14	37
Issue			2	2			4	4		1	4	5	11
⊟ All KOs | Use-cases.md											**2**	**2**	**2**
Comment											1	1	1
Issue											1	1	1
⊟ Components.md	**8**	**5**	**29**	**42**	**9**	**4**	**21**	**34**	**26**	**11**	**96**	**133**	**209**
approval comment							2	2					2
Comment		4	13	17		1	2	3	5	11	31	47	67
Commit	8		13	21	8		11	19	16		54	70	110
Issue		1	3	4	1	3	6	10	5		10	15	29
review comment											1	1	1
⊟ Components.md | Interactions.md			**1**	**1**									**1**
Comment			1	1									1
⊟ Definitions.md									**3**		**17**	**20**	**20**
Comment											8	8	8
Commit									3		5	8	8
Issue											3	3	3
review comment											1	1	1
⊟ Design Critique template.md	**2**		**5**	**7**									**7**
Comment			2	2									2
Commit	2		3	5									5
⊟ Design critique.md					**8**	**3**	**35**	**46**					**46**
Comment						3	11	14					14
Commit					7		14	21					21
Issue					1		6	7					7
review comment							4	4					4
⊟ Interactions.md	**17**	**5**	**26**	**48**	**10**	**4**	**27**	**41**	**24**	**13**	**67**	**104**	**193**
approval comment							1	1					1
Comment		4	3	7		2	7	9		10	29	39	55
Commit	17	1	16	34	10		11	21	24		30	54	109
Issue			7	7		2	8	10		3	8	11	28
⊟ Reading Summaries.md	**4**		**14**	**18**									**18**
Comment			5	5									5
Commit	4		5	9									9
Issue			4	4									4
⊟ README.md	**20**	**1**	**38**	**59**	**20**	**12**	**41**	**73**	**13**	**6**	**24**	**43**	**175**
approval comment						1	1	2					2
Comment		1	4	5		5	13	18		3	9	12	35
Commit	20		33	53	18		10	28	13		13	26	107
Issue			1	1	2		6	8		3	1	4	13
PR Comment						3	8	11					11
review comment						3	3	6			1	1	7
⊟ README.md | Definitions.md										**6**		**6**	**6**
Comment										5		5	5
Issue										1		1	1
⊟ Use-cases.md	**16**	**8**	**23**	**47**	**14**	**4**	**68**	**86**	**23**	**50**	**79**	**152**	**285**
approval comment							1	1					1
Comment		6	4	10		4	20	24	3	49	40	92	126
Commit	16		13	29	11		34	45	18		27	45	119
Issue		2	6	8	3		11	14	2	1	12	15	37
review comment							2	2					2
⊟ Use-cases.md | Components.md							**1**	**1**					**1**
Comment							1	1					1
⊟ Use-cases.md | Interactions.md										**1**		**1**	**1**
Comment										1		1	1
Grand Total	**67**	**19**	**142**	**228**	**61**	**27**	**216**	**304**	**89**	**95**	**296**	**480**	**1012**

More detailed results follow, with further discussion in the next chapter.

5.10.2. Knowledge object advancement and productive interactions

Charts depicting the knowledge object advancement and productive interactions indicate the frequency and timing of activity occurring between two or more participants that leads to improvements to a knowledge object, as well as all changes to knowledge objects. The ratio of productive interactions to knowledge object advancements indicates the sharedness of the document co-construction. A key to interpreting the chart presentation is below at Table 33.

Table 33: Key to interpreting charts representing knowledge object advancement and productive interactions.

Activity	Chart code	Chart visual representation
Knowledge Object Advancement	KA	Bars
Productive Interaction	KP	Circles (with lines if sequential data points)
Documents	Listed by title	Colour-coded

5.10.3. Issues and comments by knowledge object

Charts depicting the Issues and comments related to knowledge objects shows the frequency and timing of technology-mediated object-oriented interactions for each knowledge object. The number of interactions indicates the level of epistemic and regulative activity engaged in by the team during each knowledge object's development. A key to interpreting the chart presentation is below at Table 34.

Table 34: Key to interpreting charts representing Issues and comments for each knowledge object.

Activity	Chart code	Chart visual representation
Issue	Issue	Bars
Comment	Comment	Circles (with lines if sequential data points)
Documents	Listed by title	Colour-coded

5.10.4. Actions and interactions by team member

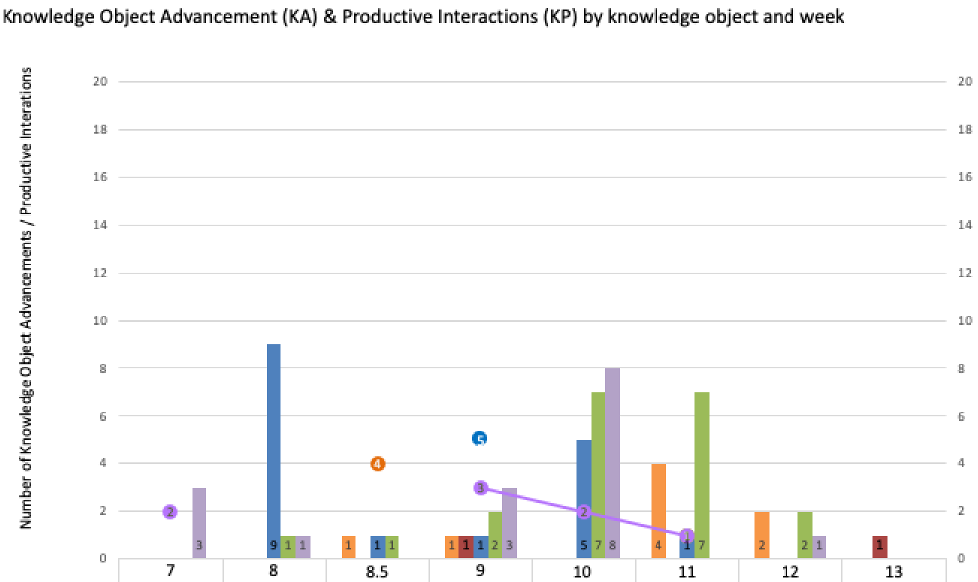
Charts depicting the actions and interactions for each team member in relation to specific knowledge objects show the frequency and timing of individual contributions that are productive, advance the knowledge object, or neither. The number and proportion of actions and interactions in each area for each team member indicates the way in which they contributed to the collaboration. These charts have two axes at the same scale, with actions that advanced the knowledge object or were productive in the lower half of the graph, and other actions in the top half of the graph. A key to interpreting the chart presentation is below at Table 35.

Table 35: Key to interpreting charts representing the activity in Issues, comments and Commits for all team member by productivity and outcome.

Activity	Chart code	Chart visual representation
Comment – knowledge object advancement	Comment - KA	Yellow bar in lower half
Comment – productive	Comment -KP	Orange bar in lower half
Comment – other	Comment – other	Orange circle in upper half
Commit – knowledge object advancement	Commit – KA	Green bar in lower half
Commit – productive	Commit – KP	Dark green bar in lower half
Commit – other	Commit – other	Green dot in upper half
Issue – knowledge object advancement	Issue – KA	Light blue bar in lower half
Issue – productive	Issue – KP	Blue bar in lower half
Issue – other	Issue – other	Blue diamond in upper half

5.11. Team A

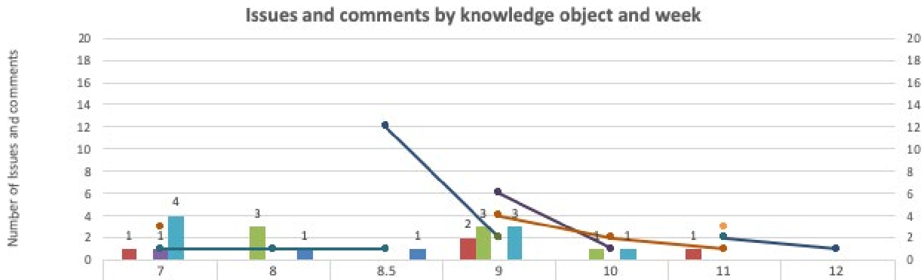
A breakdown of knowledge object advancements and productive interactions for Team A is at Figure 42, with further detail on each document in the following sections. Team A's knowledge object development trajectory is characterised by intermittent knowledge object advancement in response to instructor-initiated tasks and the assessment submission timeframe. The productive interactions were associated with additions of specific sections of each knowledge object without subsequent discussion.



	7	8	8.5	9	10	11	12	13
KA - Components.md			1	1		4	2	
KA - Design Critique template.md				1				1
KA - Interactions.md		9	1	1	5	1		
KA - README.md		1	1	2	7	7	2	
KA - Use-cases.md	3	1		3	8		1	
KP - Components.md			4			1		
KP - Interactions.md				5				
KP - README.md						1		
KP - Use-cases.md	2			3	2	1		

Figure 42: Team A knowledge object advancement and productive interactions by week and knowledge object.

Team A's interaction frequency remained low through the teaching session in relation to all knowledge objects as shown at Figure 43 below. The additional activity in Week 8.5 on *Components.md* reflects attempts to upload a diagram.



	7	8	8.5	9	10	11	12
Issue - Components.md	1			2		1	
Issue - Interactions.md		3		3	1		
Issue - README.md	1						
Issue - Use-cases.md	4			3	1		
Issue - All KOs		1	1				
Comment - All KOs			1			3	
Comment - Components.md			12	2		2	1
Comment - Components.md | Interactions.md		1					
Comment - Design Critique template.md				2			
Comment - Interactions.md				6	1		
Comment - README.md	1	1	1			2	
Comment - Use-cases.md	3			4	2	1	

Figure 43: Team A Issues and comments by knowledge object and week.

5.11.1. Use-cases.md

The Use-cases.md knowledge object evolved principally through individual additions of specific models with associated code. Interactions were generally regulative in nature, for example, asking "Hey guys…One specific diagram that we forgot to allocate was the Design Element selector function…It acts almost as a shopping cart that collaborators can use to create unique learning designs…Can someone please tackle this one?".

Team members were confused about where to locate their work, for example, A3 simply pasted a model into a comment in an Issue and then closed the Issue, indicating there may not have been a shared understanding of the task or environment. This is also visible in the comment "Hey all is this the right place for this? … I finally figured out how to create a simple UML diagram.

Figure 44 shows the development trajectory of *Use-cases.md*. In the following Figures 43-46, knowledge object advancement and productive actions and interactions are shown below the line and unproductive other interactions above the line.

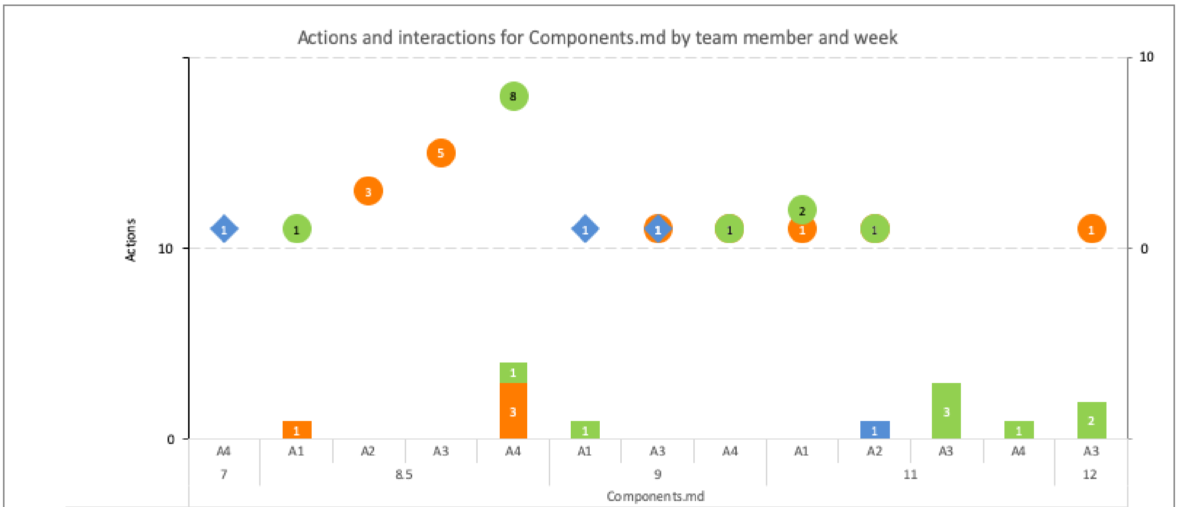
Week	7		8	9				10				11		12
Member	A1	A2	A2	A1	A2	A3	A4	A1	A2	A3	A4	A1	A2	A2
Issue - KP		1			1									
Commit - KA	1	2	1	1	2			1		2	5			1
Comment - KP		1				1	1				2		1	
Comment - other	2				1	1								
Commit - other		2			2				1	1	5	1		1
Issue - other	1	2			2						1			

Figure 44: Knowledge object advancement and productive interactions for Use-cases.md by team member and week.

The GitHub data does not reveal shared planning for *Use-cases.md,* and the final knowledge object displays minor inconsistencies between the models which might reflect these individual contributions. The higher level of activity in Week 10 reflects an Issue raised in Week 9 noting an additional model was required, and the multiple actions by the author to develop the model and correct its formatting and display syntax. There was no observable feedback on model design leading to changes. Only one model was amended after initial drafting by the original author and the reason for the changes is not indicated in the related Commit comment.

5.11.2. Components.md

The actions and interactions in relation to *Components.md* were also mostly regulative, with the high number of unproductive actions mostly related to team members struggling to use the UML notation and uploading diagrams constructed in PowerPoint instead, in the case of one team member, in multiple locations. The productive interactions in Week 8.5 illustrate one team member assisting one of the two team members who had uploaded the PowerPoint graphics. There was little discussion around the models within the team as shown by the low number of interactions in relation to this knowledge object, and the lack of modifications to the models as initially drafted. Figure 45 shows the development trajectory of *Components.md.*



Teaching Week	7	8.5				9			11				12
	A4	A1	A2	A3	A4	A1	A3	A4	A1	A2	A3	A4	A3
Issue - KP										1			
Commit - KA					1	1					3	1	2
Comment - KP		1			3								
Comment - other			3	5			1	1	1	1			1
Commit - other		1			8			1	2	1			
Issue - other	1					1	1						

Figure 45: Knowledge object advancement and productive interactions for Components.md by team member and week.

5.11.3. Interactions.md

Team A's *Interactions.md* had a relatively high number of Commits compared to their other knowledge objects. The models were constructed by only two team members, with the initial activity in Week 8 reflecting iterative addition of models and narratives, and some adjustments to the model syntax for correctness.

The high number of unproductive Commits in Week 9 relate to one team member having the same problems creating and uploading their UML model as they experienced in relation to the use-cases document, and in Week 11 the Commits are minor formatting and text tidying.

The design critique task in Week 9 did generate a comment from each team member (in one case duplicated), but as none of the models were amended to incorporate this feedback they have not been considered productive interactions. Knowledge object advancement in Weeks 10 and 11 was the addition of models which had been assigned to other team members who had left the group or not completed their allocated task. Commit comments were generally absent so provided little insight into the authors' theoretical rationale or the group's objectives. Figure 46 shows the development trajectory of *Interactions.md*.

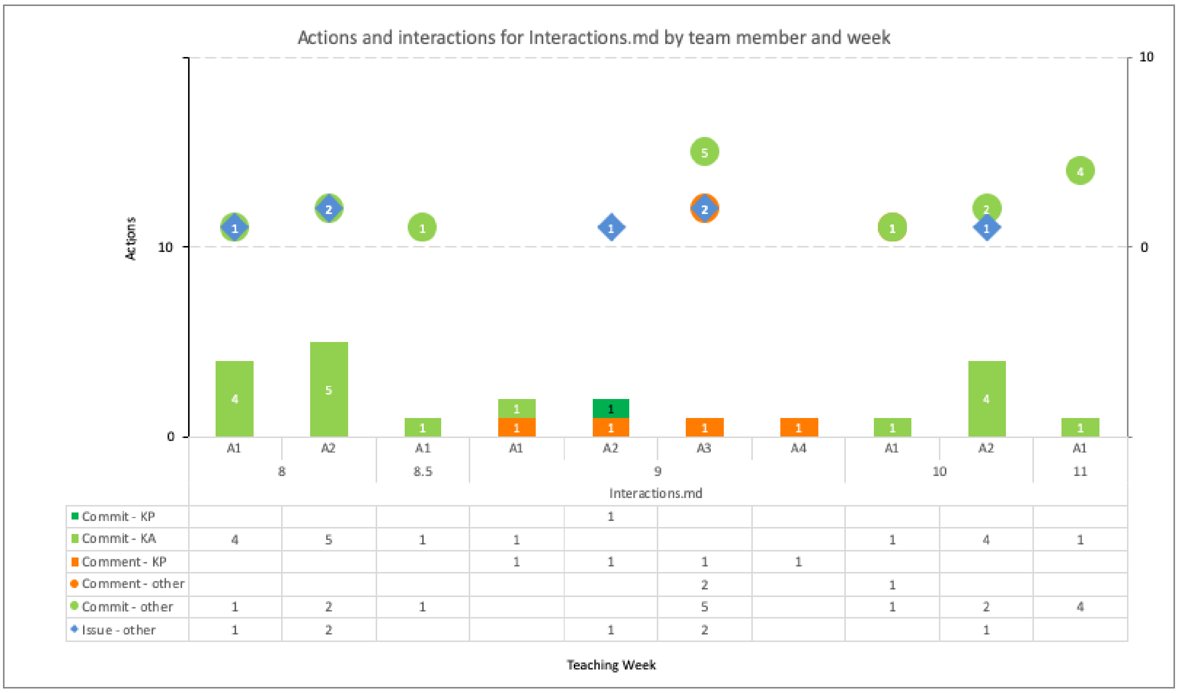


Figure 46: Knowledge object advancement and productive interactions for Interactions.md by team member and week.

5.11.4. README.md

Team A's *README.md* generated the most knowledge-object-based activity, with 59 out of a total of 227 interactions. Most development was done by two team members in Weeks 10 and 11, just prior to task submission. The single productive interaction was conceptually regulative, with one team member advising another that a narrative section required completion, resulting in the creation of that section by the other team member. The GitHub data did not show discussion within the group about the content or development process, and edits to the sections once drafted comprised only minor text or formatting changes. Figure 47 shows the development trajectory of *README.md*.

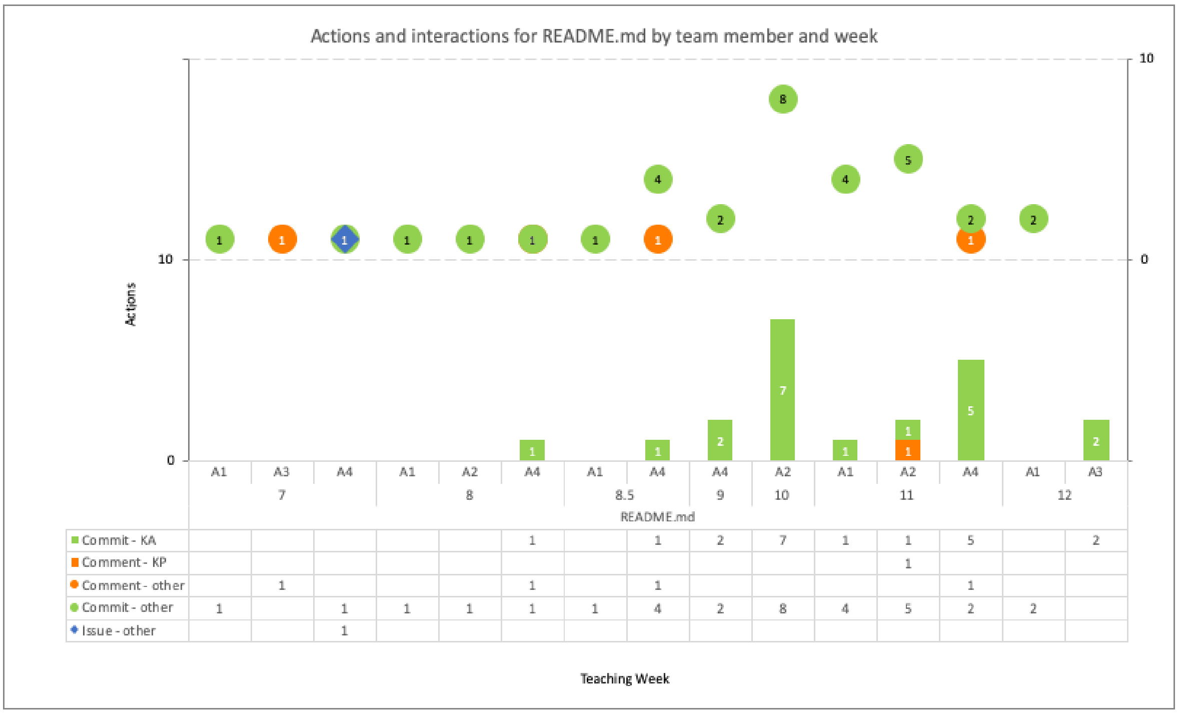


Figure 47: Knowledge object advancement and productive interactions for README.md by team member and week.

5.11.5. Design critique template.md

In response to the Team's Design Critique task in Week 9, a team member created an intermediate artefact setting out guidelines for conducting a design critique although they did not specify the source of the framework. They commented that the template was available and it was clear that the next team members to conduct their critique had used it; A1 starts their critique by mentioning it "Hi all,...Thanks @[A4] for the template! I've tried to follow if for my critique below.", and later states "Please see my comments using the design Critique process for the diagram" and uses the framework's structure. This development is productive, as after drafting, the document is edited once in Week 13 by another team member to add a UML model of the process which is then also added to Use-cases.md. While a comment also recommends a link to the template be included in the *README*, that was not done.

5.11.6. Reading summaries

Team A created a second document set additional to the task requirements in Weeks 7 and 8. After one team member uploaded a summary of a relevant reading, two other team members also uploaded summaries of different readings. There was no further reference to these documents except for a name change of their containing folder.

5.11.7. Summary

Team A produced a set of knowledge objects which met the task requirements. The GitHub data showed a high proportion of actions and interactions that did not advance the knowledge objects: trial and error interactions with the environment, task coordination, and minor text editing. A summary of the proportion of actions and interactions that were productive, advanced the knowledge object, or neither, is at Figure 48 below.

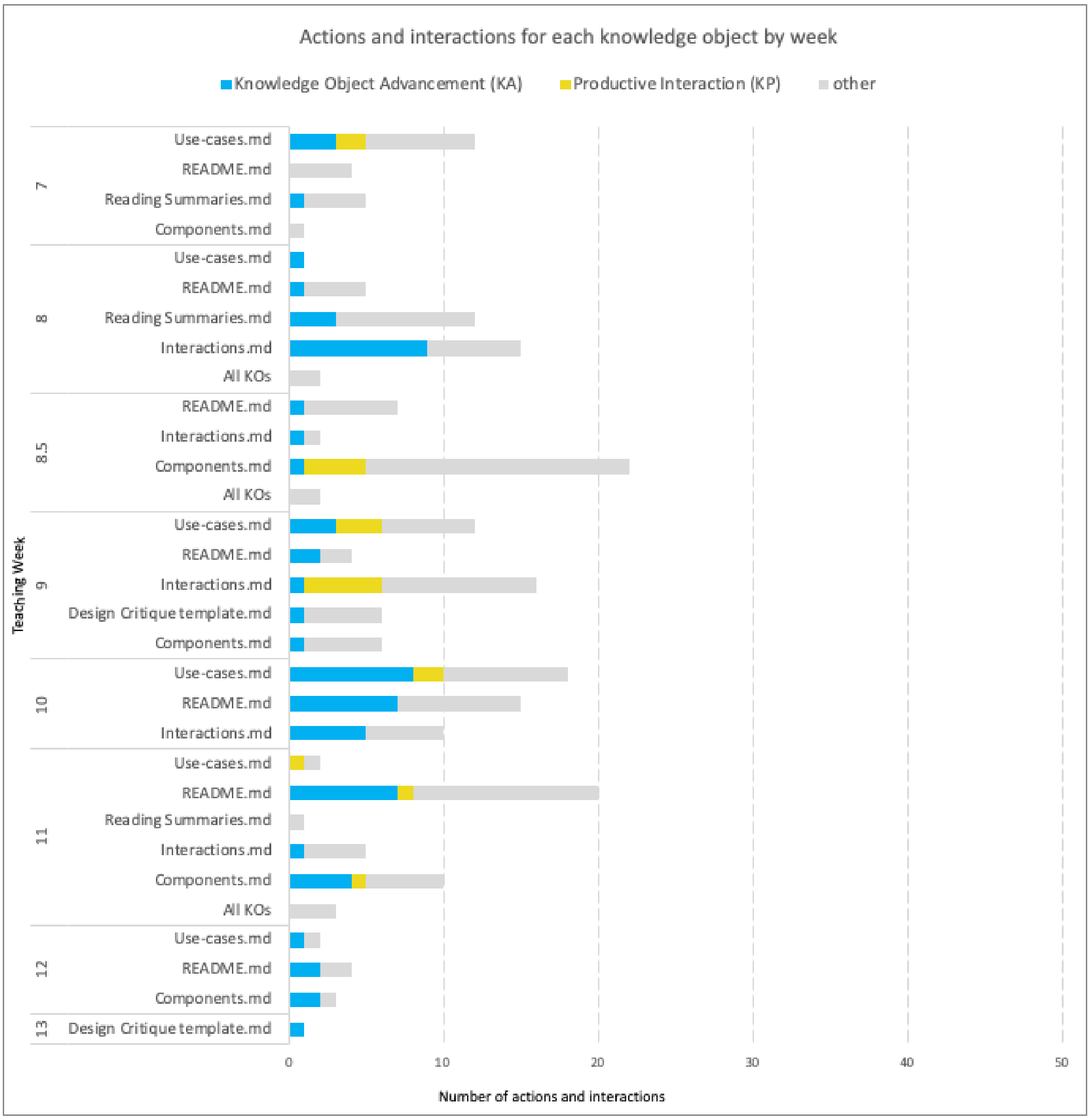
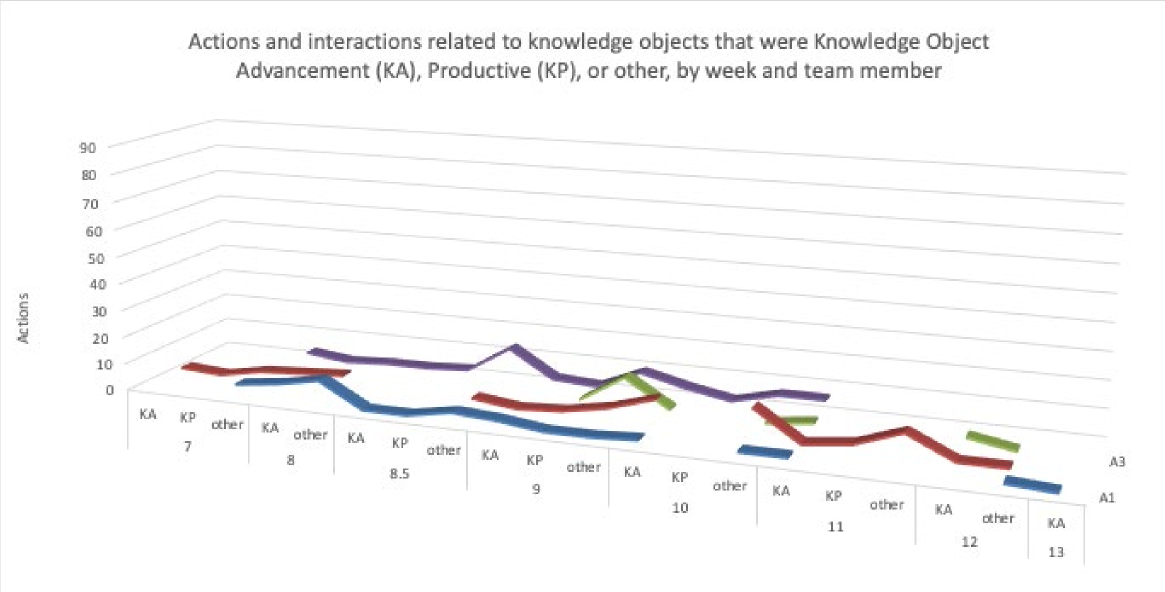


Figure 48: Summary of the productivity of knowledge object-related actions by week.

Model construction appeared to be done independently and feedback rarely sought or provided, nor responded to. The Issues and comments showed little engagement by the group with some team members' repeated problems with UML coding and the location of models within the repo. The team did generate additional knowledge objects in the reading summaries and design critique framework, and it was visible that the critique framework was used.

It generally appears that one person would do the different model types of a particular scenario, for example, A1 adds a use case for integration of different design elements, and subsequently an interaction model for integration of different design elements. In that example, the models are not substantially different, potentially showing a lack of familiarity with the purpose of the different model forms. There was not evidence of sustained engagement with knowledge object advancement at group level.

Comments indicated one team member was considered to be authoritative, as they were asked and told others what work needed to be done. A different team member helped another with a UML diagram by constructing the diagram for them. There was a generally low level of participation across the team, and across the project, with an uneven distribution of contribution as shown at Figure 49 below. There was little evidence of negotiated goals, shared decision making or the generation, elaboration and integration of shared meaning.

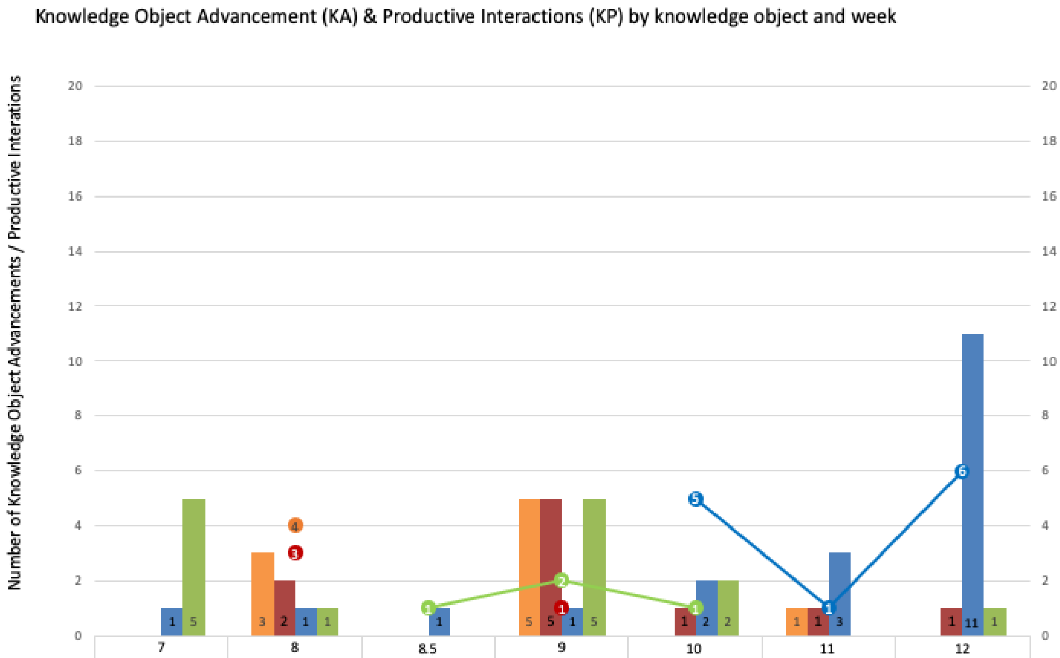


	7			8		8.5			9			10			11			12		13
	KA	KP	other	KA	other	KA	KP	other	KA	KP	other	KA	KP	other	KA	KP	other	KA	other	KA
A1	1		5	7	10	1	1	4	3	1	1	2		2	2		13		2	1
A2	3	2	5	6	7			4	2	3	6	11		12	1	3	9	1	1	
A3			3		2			5		2	12	2		1	3			4	1	
A4			3	1	2	2	3	13	3	2	9	5	2	6	6		4			

Figure 49: Knowledge Object Advancements, Productive Interactions and interactions and actions that were neither but related to Team A's tasked knowledge objects by team member and week.

5.12.Team B

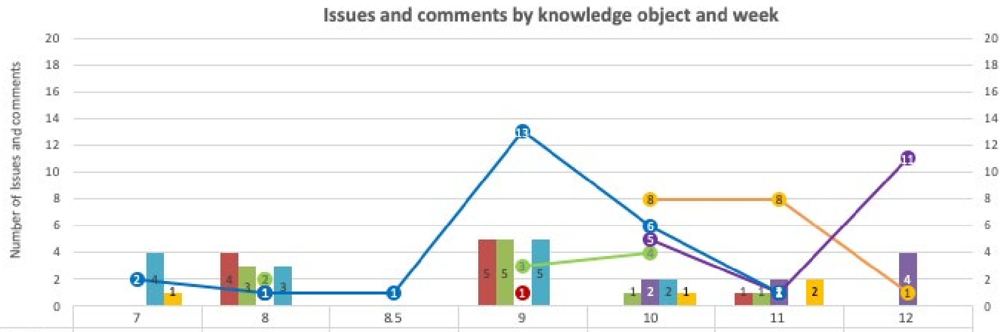
A breakdown of knowledge object advancements and productive interactions for Team B is at Figure 50 with further detail on each document below. Team B's knowledge object development trajectory is characterised by active knowledge object advancement that becomes more consistent across the knowledge objects from Week 9. Productive interactions become more sustained over time in relation to the discussion around the *README* and the inclusion of particular terminologies.



	7	8	8.5	9	10	11	12
KA - Components.md		3		5		1	
KA - Interactions.md		2		5	1	1	1
KA - README.md	1	1	1	1	2	3	11
KA - Use-cases.md	5	1		5	2		1
KP - Components.md		4					
KP - Interactions.md		3		1			
KP - README.md					5	1	6
KP - Use-cases.md			1	2	1		

Figure 50: Team B knowledge object advancement and productive interactions by week and knowledge object.

Team B's interaction frequency remained at a moderate level as shown at Figure 51 below, sustained over almost all weeks in relation to *Use-cases.md*, with the peak in Week 9 reflecting the discussion around the Design Critique task, the contribution of notes on pedagogies, and unactioned feedback on a range of knowledge objects.



	7	8	8.5	9	10	11	12
Issue - Components.md		4		5		1	
Issue - Interactions.md		3		5	1	1	
Issue - README.md					2	2	4
Issue - Use-cases.md	4	3		5	2		
Issue - All KOs	1				1	2	
Comment - All KOs		2			8	8	1
Comment - Components.md		1		1		1	
Comment - Interactions.md		2		3	4		
Comment - README.md		1			5	1	11
Comment - Use-cases.md	2	1	1	13	6	1	

Teaching Week

Figure 51: Team B Issues and comments by knowledge object and week.

5.12.1. Use-cases.md

Analysis of Team B's use-cases document was confounded somewhat by their use of multiple documents. Their initial use case designs were contained in *Use-cases.md*, but after the Week 9 instructor task to develop design critique functionality within the designed learning environment they also created a separate document design critique.md which contained use cases specifically related to this design critique. In Week 9, there was also an instructor task for each team to critique their most advanced model to date, and while Team B selected their Use Case 2 model to critique, it isn't clear from the critique whether they are critiquing the *Use-cases.md* document or the design critique.md document. For this reason, all feedback in the design critique task have been taken to apply to either or both the *Use-cases.md* and the *Design critique.md* document. The *Use-cases.md* document generated the most comments of all the knowledge objects, but not by a great amount. Figure 52 shows the development trajectory of *Use-cases.md.* In the following Figures 52-56, knowledge object advancement and productive actions and interactions are shown below the line and unproductive other interactions above the line.

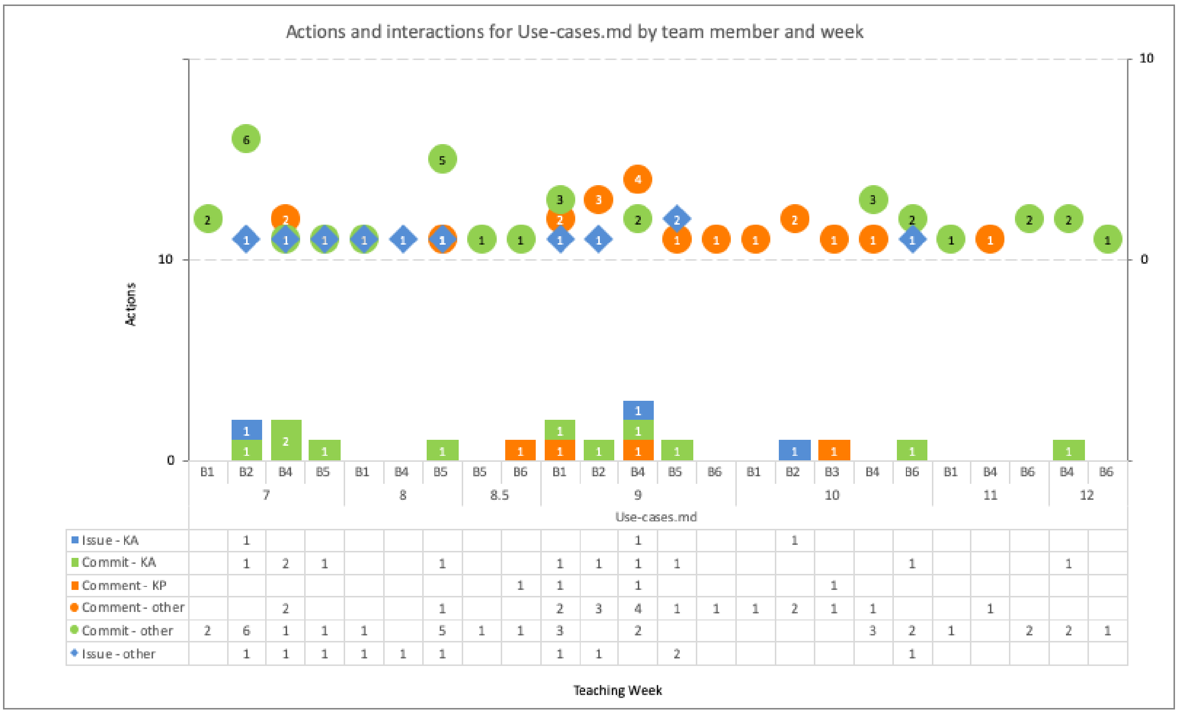


Figure 52: Knowledge object advancement and productive interactions for Use-cases.md by team member and week.

Overall, there were few ways to tie specific GitHub interactions with particular actions on the knowledge objects as the Issue/Pull Request function was used inconsistently and a relevant knowledge object not always mentioned, but more abstract relationships could be observed. For example, an Issue titled "Work on use case narratives" has a checkbox "Come up with use cases for different platforms", and at in another instance specific team members were assigned to create finalised use cases "as discussed in the meeting" so we could consider all work in the two weeks following to be generated my more than one participant.

Where the Issue or Pull Request feature of GitHub was used to gather feedback from others, it was possible to observe more direct outcomes of interactions. This occurred several times, as shown at Table 36. However, this shows us more of the productional work than the epistemic work the group are doing together. The Issue relating to the design critique gathered the most (ten) comments and is attached in full at Appendix J.

Table 36: Team B's observable concrete changes to knowledge objects after related interactions.

Reference	Productive interaction	Subsequent advancement
Issue 28	I think student data should go to the dashboard first before the teacher. In this case, the dashboard is the "information space".	in light of [B1's] feedback I've added a mediated step between teacher & data called the dashboard.
Comment 1273	In short, we need to consider Analytics Technology, Mixed Reality, AI and Virtual Assistants.	Added data collection/processing use case
Issue 27	I have gone to do this and realised I am not completely sure what it means - because I feel that our second use case "at a micro level" does this well. Sorry if I have misunderstood what I needed to do. Any suggestions/clarifications would be very appreciated!	Have a look at the use case I have put in with its narrative/justification. I have also jiggled a few things around such as renaming the Instructional Designer to Learning Designer, and put in that the Unique Learning Environment selects the Online Content rather than vice versa.
Comment 1475	This looks good- but should it be sitting in the file I created called Design Critique.md? there are two use cases there already.	added previous design critique use case from use cases doc
Comment 1746	However my question would be where is the user data coming from? In the first instance of a designer building a system like this, they would not have user behaviour to go off. They would have to create, and then get user data, and then amend. Should we move these points further down into the diagram?	I've removed the data collection for the first diagram and made it clear this is a big picture view of the design process (pre-use). Then the 2nd diagram shows at a micro level how the design critique can be incorporated once the design is being used.

There were two edits where it was clear that the model authors were attempting to incorporate the ideas of others into their work. In one Issue, B2 comments "I have had a go combining [B4] and my Use case diagrams. Please let me know if I have made any major mistakes or if there is anything you would like to change.", referring to the addition of their diagram into the same document as another team member's. The other team member asks if they can be 'merged' (in the sense of combining rather the GitHub sense of committing to the master branch) but this is not followed up by the author. In another, B4 adds two new use cases in *Design critique.md* but uses elements of those already in *Use-cases.md* in their construction.

In most instances, each team member added and then tidied one or more specific models and did not edit each other's contributions. While it is possible that the team may have collaboratively designed the models in meetings and then left it to individuals to produce the code, the participants' response to input about the models did not suggest a continuing evolution of design. This is illustrated by the suggestions which were not incorporated in the model designs. For example, an Issue was raised to gather "pedagogical research that supports our scenarios", but it was not incorporated in the team's designs, even where specifically relevant, and the 'immersive' learning environment added included none of the pedagogical approaches, or technologies, mentioned.

Other examples of missed opportunities for development were the Design Critique, where feedback about the use case models are not addressed in either the *Use-cases.md* or *Design critique.md* versions and in another Issue, where a suggestion that adaptive learning technologies be incorporated into the modelling was not taken up. Specific feedback on model structure went unanswered, as did a question about how to combine models.

There was engagement from others in asking questions about the knowledge objects, and in some cases these were answered by either the original author or others. These have been detailed in the data analysis if they could not be understood as either making concrete suggestions which were not incorporated, or leading to changes to a knowledge object.

5.12.2. Components.md

The *Components.md* document was principally edited by a single team member, but it built on the perspectives of others and continued to evolve over time. Figure 53 shows the development trajectory of *Components.md*.

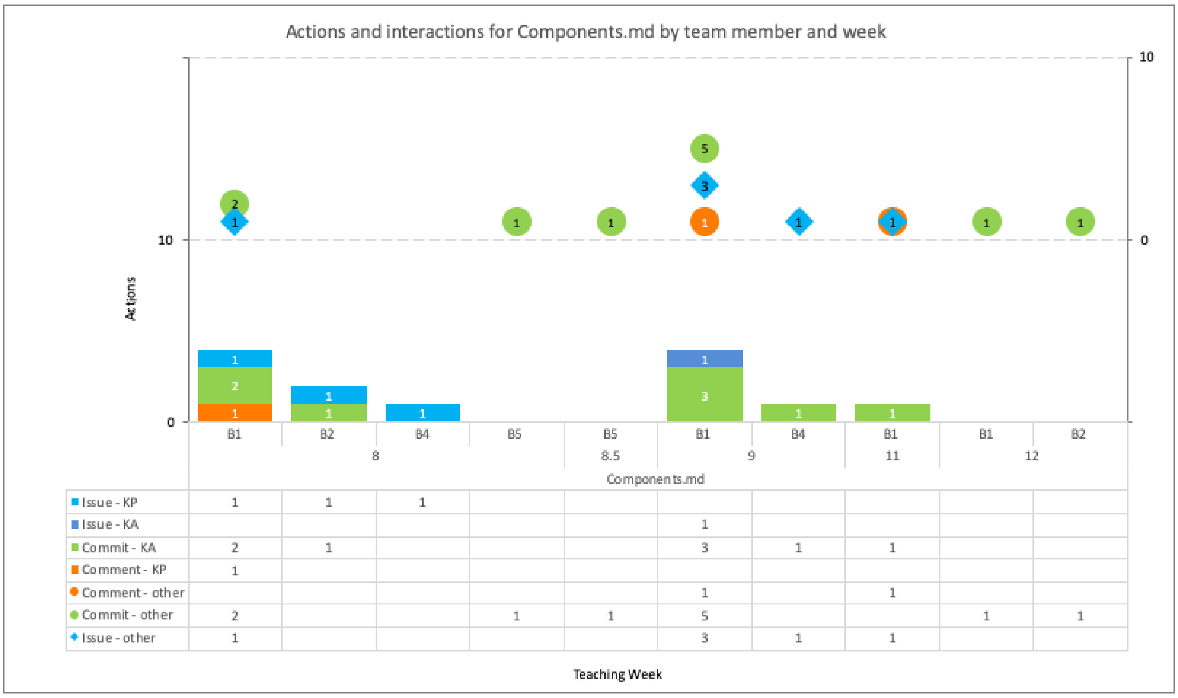


Figure 53: Knowledge object advancement and productive interactions for Components.md by team member and week.

Two comments from the GitHub data at Table 37 demonstrate this unfolding process.

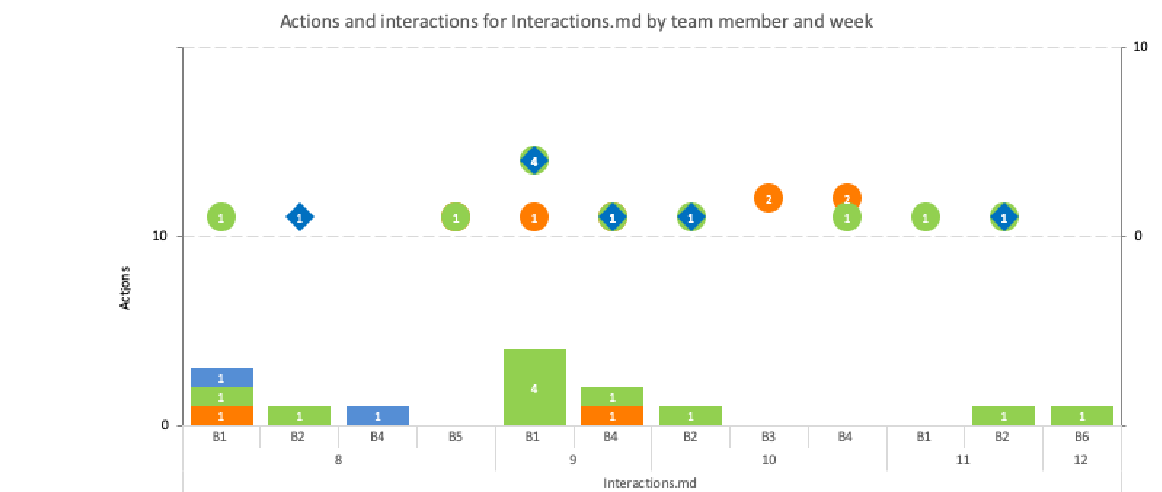
Table 37: Excerpts from GitHub interaction data showing collaborative approach to ongoing knowledge object development.

Reference	Productive interaction	Subsequent advancement
Issue	Please ignore my first update on narrative #2. I forgot to add the feedback centre. Please refer to this new version instead. Thank you!	Issue 3
Issue	I've added back in the context of the data feeding back. Do you think we need to give some context re the feedback? is this feedback about performance for the dashboards?	Comment 1327

Feedback provided in relation to *Components.md* was actioned mostly by the original author and an updated version provided to the team for review.

5.12.3. Interactions.md

The development of the *Interactions.md* document was articulated more in GitHub comments than other knowledge objects, perhaps as it was the last to be initiated and the group were more familiar with the platform. Most productive interactions occurred early on with limited activity and advancement in the last weeks of the project. Figure 54 shows the development trajectory of *Interactions.md.*



Week	8				9		10			11		12
	B1	B2	B4	B5	B1	B4	B2	B3	B4	B1	B2	B6
Issue - KP	1		1									
Commit - KA	1	1			4	1	1				1	1
Comment - KP	1					1						
Comment - other				1	1	1		2	2			
Commit - other	1			1	4	1	1		1	1	1	
Issue - other		1			4	1	1				1	

Teaching Week

Figure 54: Knowledge object advancement and productive interactions for Interactions.md by team member and week.

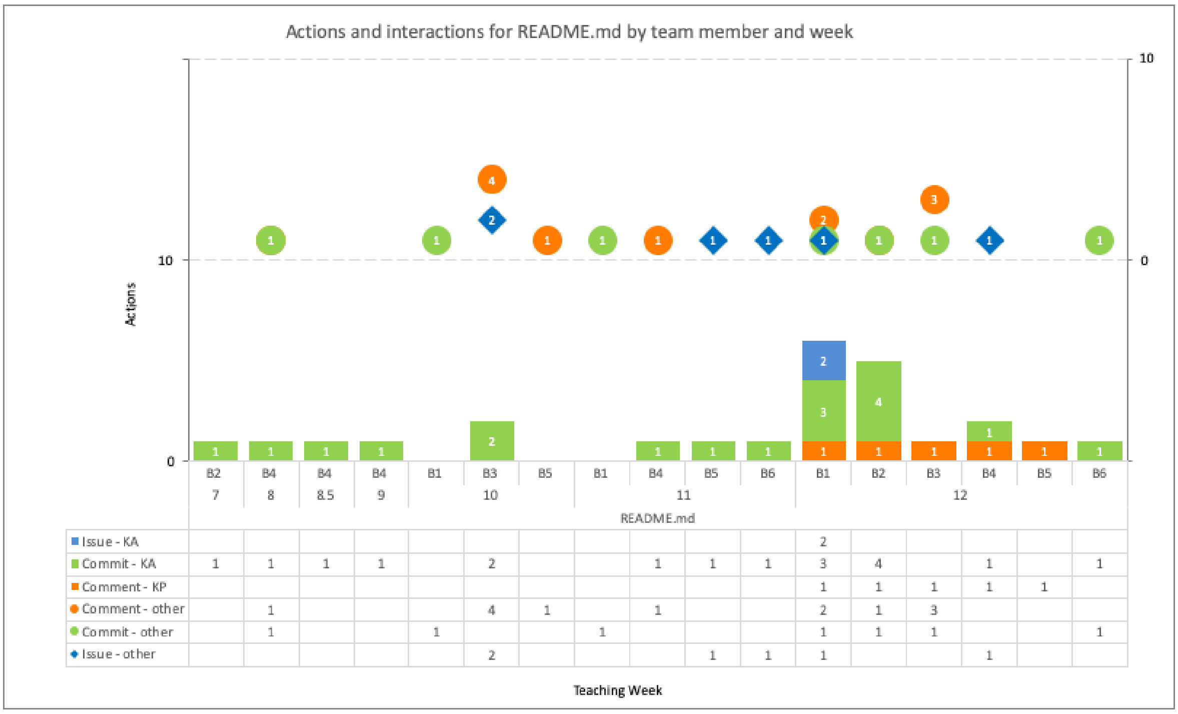
While additions to the document tended to be done by individual authors, explanations of epistemic goals were present in nearly half the Commit comments, as shown in Table 38 below. However, not all these interactions were productive.

While the team did mention *Interactions.md* in Issues and Pull Requests, the comments duplicated those made in the Commits and set out above.

5.12.4. README.md

The *README.md* contained contributions from multiple team members, and evidence of discussion of epistemic issues and sharing of knowledge between the participants. Major changes to the document by one team member in Week 10 generated comments both in the text of the document and in a related Issue around the new information that had been added, particularly the use of the term 'learning styles'. Four team members provided feedback on the new draft, with the author agreeing to remove the term from their rationale after the others had referenced an academic paper and anecdotal evidence that learning styles were not supported by sufficient academic rigour for them to believe the concept warranted inclusion as a principle for their design. Feedback was also provided on the proposed data collection and assessment modes, and the author also Committed to incorporating that into the draft. While they did remove “learning styles”, they did not follow up the other changes.

A second group conversation resulted from questions around two terms in the sentence “These productive failures will be highly supported with timely context-specific feedback generated by the software of the LDE and reinforced by the teacher.”, clarifying the use of ‘software’ and ‘reinforced’. One student asked for clarification of the term ‘filtered, and received one reply. While four team members provided related feedback on the questions, none was actioned. Figure 55 shows the development trajectory of *README.md.*

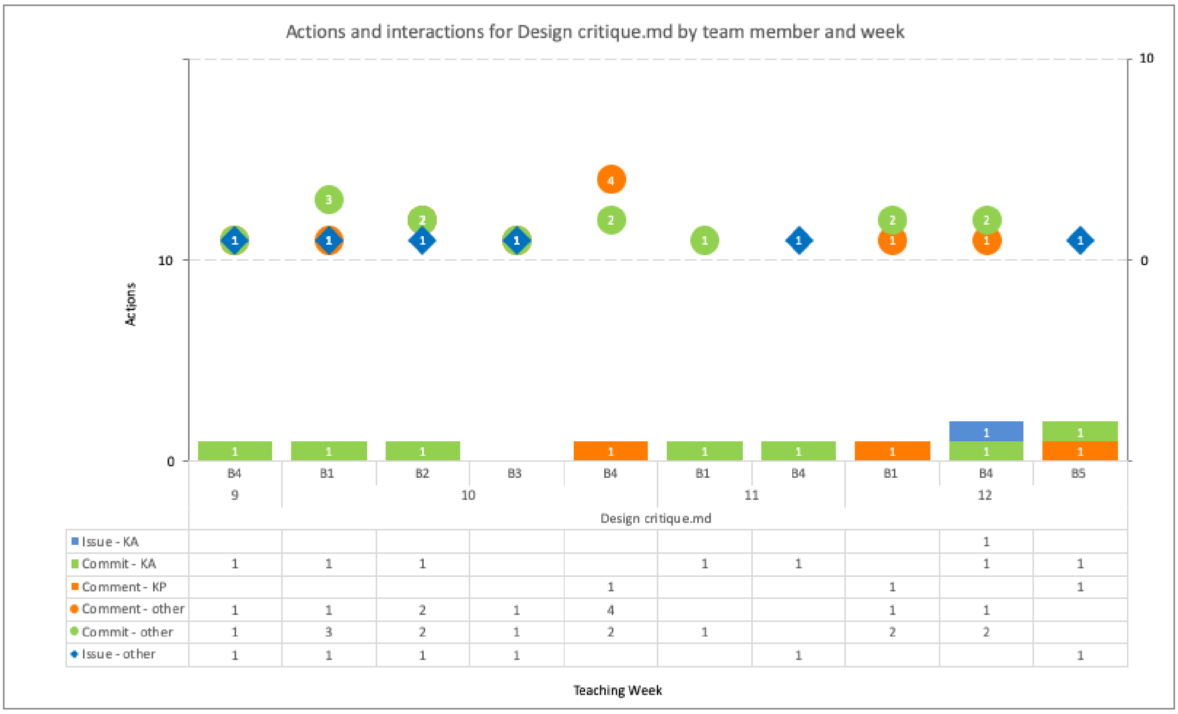


	B2	B4	B4	B4	B1	B3	B5	B1	B4	B5	B6	B1	B2	B3	B4	B5	B6
	7	8	8.5	9		10			11					12			
Issue - KA												2					
Commit - KA	1	1	1	1		2			1	1	1	3	4		1		1
Comment - KP												1	1	1	1	1	
Comment - other		1				4	1		1			2	1	3			
Commit - other		1			1			1				1	1	1			1
Issue - other						2				1	1	1			1		

Figure 55: Knowledge object advancement and productive interactions for README.md by team member and week.

5.12.5. Design critique.md

The *Design critique.md* document was an intermediate knowledge object developed by Team B probably in response to the instructor task to conduct a design critique of the team’s most advanced model so far. In initial draft by one team member, it contained a description of the design critique process, and was added to by a second participant after the instructor task to add specific use case and interaction models. A substantial modification was made without discussion in relation to the role of AI, which led to another participant removing one of the models, also without discussion. There is little evidence of a shared approach, with only one Pull Request generating feedback from others about a specific aspect of the model, which was responded to by another participant. While the response indicated modification was not required, the model was changed by the same 'remover' in a subsequent edit which was then the final version. Figure 56 shows the development trajectory of *Design critique.md.*



Teaching Week	9	10				11		12		
Team member	B4	B1	B2	B3	B4	B1	B4	B1	B4	B5
Issue - KA									1	
Commit - KA	1	1	1			1	1		1	1
Comment - KP					1			1		1
Comment - other	1	1	2	1	4			1	1	
Commit - other	1	3	2	1	2	1		2	2	
Issue - other	1	1	1	1			1			1

Figure 56: Knowledge object advancement and productive interactions for Design critique.md by team member and week.

5.12.6. Summary

Although it was not always straightforward to follow the threads of Team B's discussion about knowledge objects, the GitHub data at Figure 57 below showed some sustained epistemic activity indicating they made shared decisions about what to include in them even if that was not visible in the document editing logs.

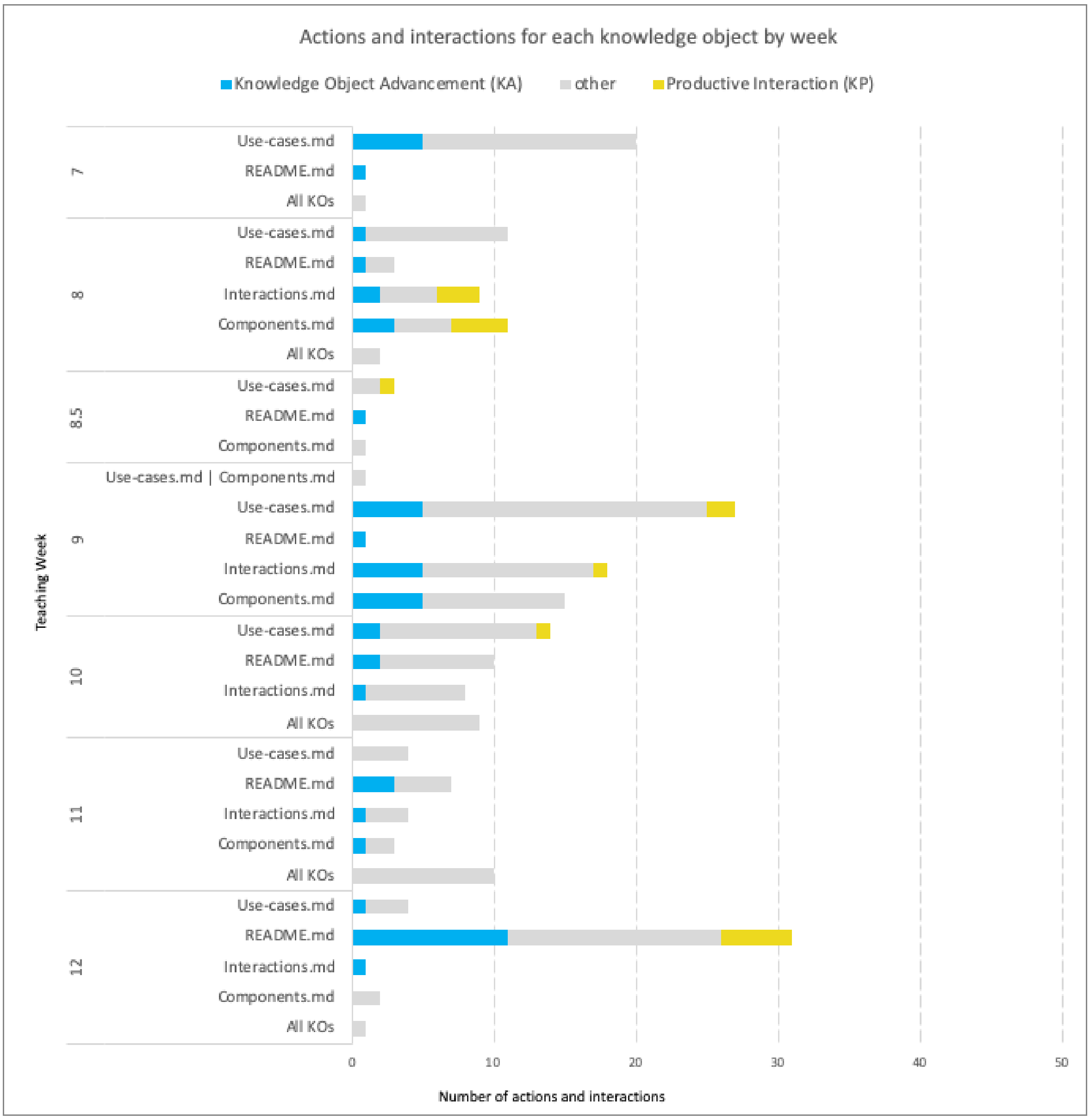
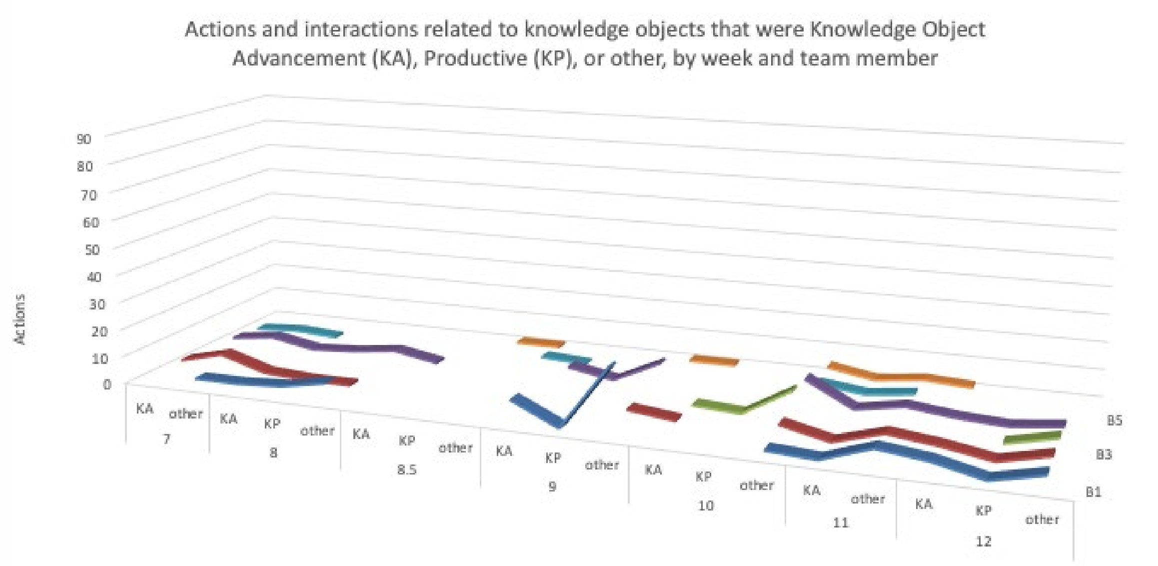


Figure 57: Summary of the productivity of knowledge object-related actions by week.

The team frequently mention meeting discussions as the impetus for changes. The data also shows purposeful use of the review workflow in GitHub, where team members can be tagged when approval of a document merge to the master thread is required.

Model construction was generally distributed at the level of diagram or narrative development, there is some evidence of sustained engagement with the knowledge objects at group level. There was engagement with a number of Issues and comments every week, but interactions only infrequently led to knowledge object advancement. The team did generate additional knowledge objects in their design critique document.

There was a generally low level of participation, across the team, and across the project, with an uneven distribution of contribution and most activity just before task submission as shown at Figure 58. There was some evidence of shared decision making and the generation, elaboration and integration of shared meaning.



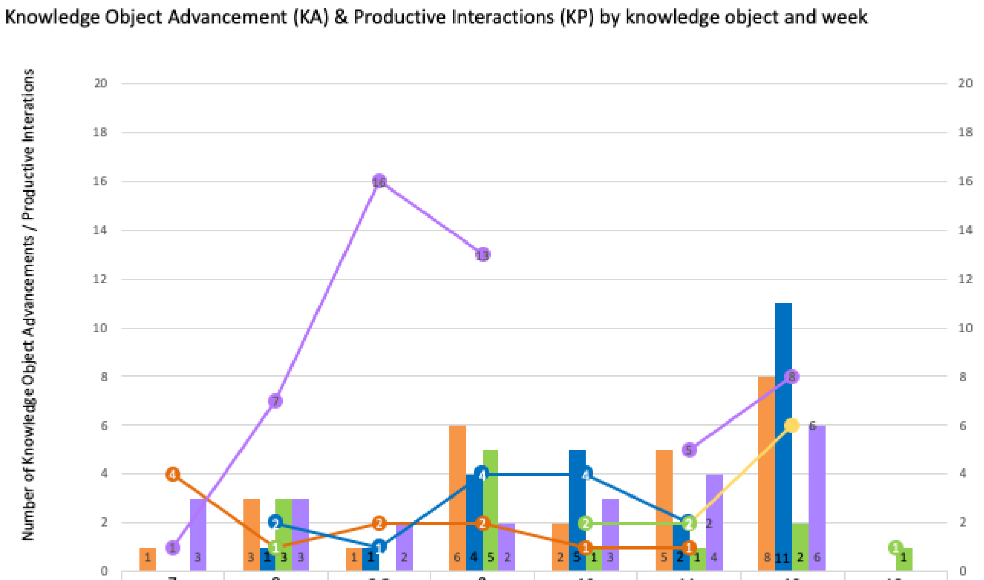
	7		8			8.5			9			10			11		12		
	KA	other	KA	KP	other	KA	KP	other	KA	KP	other	KA	KP	other	KA	other	KA	KP	other
B1		3	3	4	7				9	1	24			2	1	7	5	1	5
B2	3	7	2	1	1				1		4	2		5	1	6	4	1	5
B3												2	1	11				1	5
B4	2	4	1	2	4	1			5	2	10			10	1	4	2	1	3
B5	1	2	1		10			2	1		3			3	1	3		1	
B6							1	1			1	1		4	1	3	2		3

Week and productivity of action, by team member ■B1 ■B2 ■B3 ■B4 ■B5 ■B6

Figure 58: Knowledge Object Advancements, Productive Interactions and interactions and actions that were neither but related to Team B's knowledge objects by team member and week.

5.13.Team C

Team C's knowledge object development trajectory is characterised by both frequent productive interactions and frequent knowledge object advancement over most knowledge objects over most teaching weeks as illustrated at Figure 59 below.

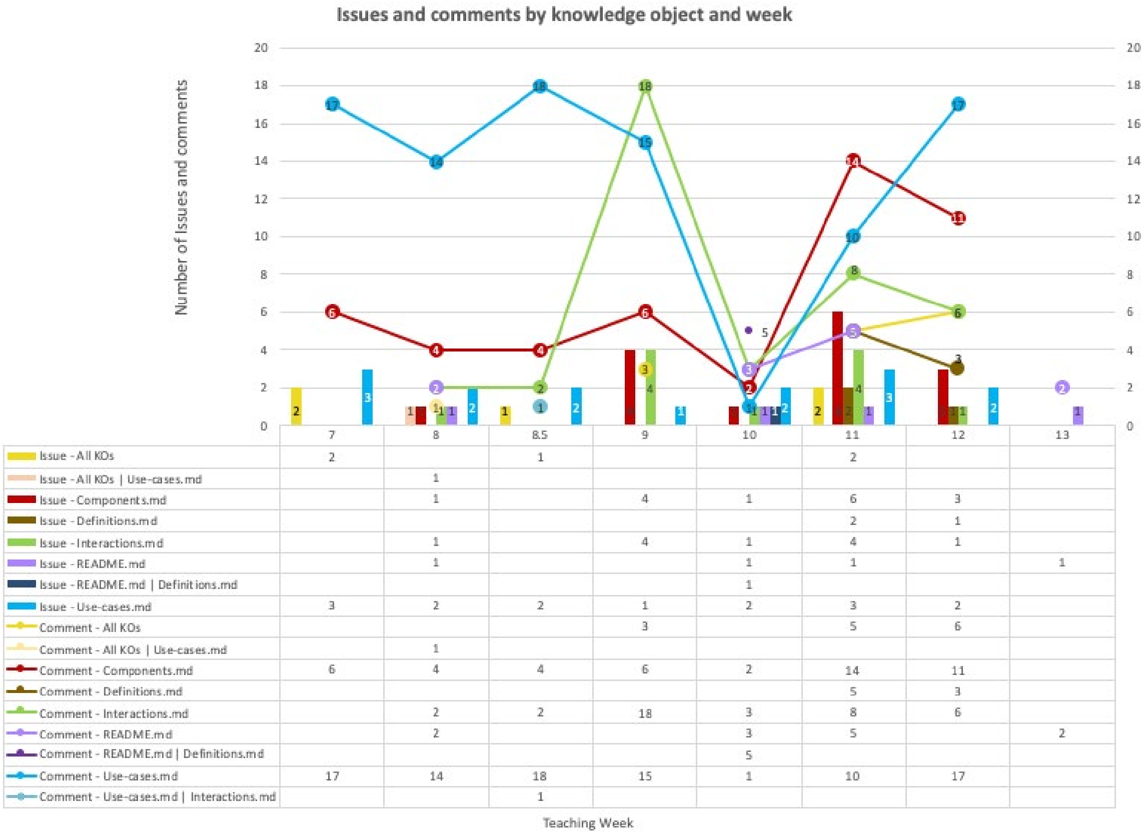


	7	8	8.5	9	10	11	12	13
KA - Components.md	1	3	1	6	2	5	8	
KA - Interactions.md		1	1	4	5	2	11	
KA - README.md		3		5	1	1	2	1
KA - Use-cases.md	3	3	2	2	3	4	6	
KP - All KOs						2	6	
KP - Components.md	4	1	2	2	1	1		
KP - Interactions.md		2	1	4	4	2		
KP - README.md		1			2	2		1
KP - Use-cases.md	1	7	16	13		5	8	

Teaching Week

Figure 59: Team C knowledge object advancement and productive interactions by week and knowledge object.

Team C showed a high level of interaction over the course of the project, generating 86 Issues and Pull Requests, twice as many as Team A and half as many again as Team B. These frequently had multiple concurrent threads, sometimes dealing with more than one knowledge object, making it difficult to link a specific comment to a specific change to a particular document. It was also clear from the data that their knowledge objects were discussed regularly in team meetings, and changes were made which did not have a GitHub interaction origin. The data also shows that as their models were interdependent, interactions were productive in relation to more than one knowledge object, for example, C3 comments "I made many changes to this repo, following the logic of the main use case scenario "Adaptive LD System"." This sustained engagement is visible at Figure 60.



	7	8	8.5	9	10	11	12	13
Issue - All KOs	2		1			2		
Issue - All KOs | Use-cases.md		1						
Issue - Components.md		1		4	1	6	3	
Issue - Definitions.md						2	1	
Issue - Interactions.md		1		4	1	4	1	
Issue - README.md		1			1	1		1
Issue - README.md | Definitions.md					1			
Issue - Use-cases.md	3	2	2	1	2	3	2	
Comment - All KOs				3		5	6	
Comment - All KOs | Use-cases.md		1						
Comment - Components.md	6	4	4	6	2	14	11	
Comment - Definitions.md						5	3	
Comment - Interactions.md		2	2	18	3	8	6	
Comment - README.md		2			3	5		2
Comment - README.md | Definitions.md					5			
Comment - Use-cases.md	17	14	18	15	1	10	17	
Comment - Use-cases.md | Interactions.md			1					

Figure 60: Team C Issues and comments by knowledge object and week.

5.13.1. Use-cases.md

The GitHub data showed that Team C decided early in the project the *Use-cases.md* document would act as the parent scenario for their other models, and spent time discussing ideas, rejecting, testing, and reintroducing concepts over the course of the project including in the week of task submission. The discussion also involved more team members making significantly more comments than on any other knowledge object. As well as generating more comments by more team members, interest in *Use-cases.md* was maintained throughout the project, with no week having fewer than six comments and productive interactions maintained throughout the weeks.

Figure 61 shows the development trajectory of *Use-cases.md.* In Figures 61-64, knowledge object advancement and productive actions and interactions are shown below the line and unproductive other interactions above the line., with knowledge object advancement and productive actions and interactions shown below the line and unproductive other interactions above the line.

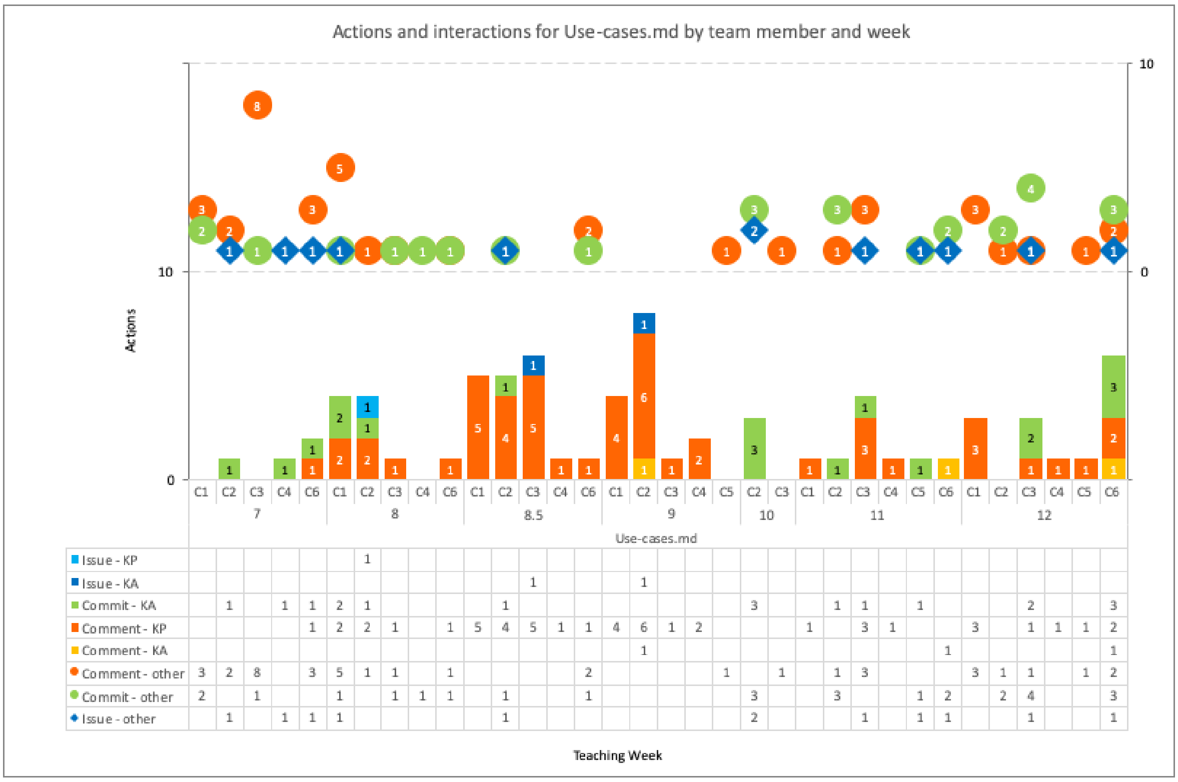


Figure 61: Knowledge object advancement and productive interactions for Use-cases.md by team member and week.

The team's document update approval process made fairly consistent use of the Issue and Pull Request functions of GitHub, so on one hand comments about each knowledge object were easier to locate than for Team B. On the other hand, of the group's 62 knowledge object-related Issues, 16 focused on the *Use-cases.md*, and discussion generated around 100 comments of the team's total of 235 knowledge-object related comments, so changes to the knowledge object were often the result of multiple inputs and discussion rather than specific, targeted feedback. The volume of comments is too large to reproduce entirely here, but there are several Issues which make it clear that feedback was taken seriously, misunderstandings were clarified, and the changes to the knowledge object were generally agreed on by the whole team before committing. Table 38 shows 4 excerpts.

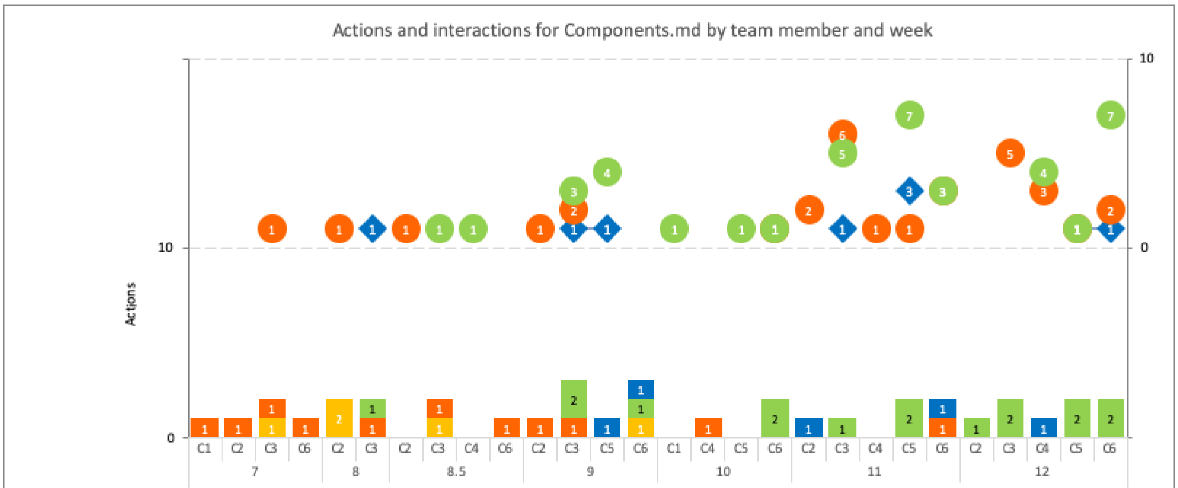
Table 38: Team C's observable concrete changes to knowledge objects after related interactions.

Reference	Productive interaction	Subsequent advancement
Issue	The various work and models that everyone is doing over the holidays and to decide if a meeting is needed during this time [*21 comments followed*]	Reversion to original model after discussing newer version in conjunction with instructor feedback and method to roll back changes.
Issue	Please review Use cases 1 and 2 to see if they are appropriate. Critique and propose any changes. To see the models, scroll down to each 'Submit Rule' http link and insert in a new tab. [*15 comments followed*]	Additions to model to integrate design critique, adjustment and course approval process for designers and instructors.
Issue	Please critique! [users tagged] My attempt at Use Case Diagram for IoT [*7 comments followed*]	Reworded narrative, expanded narrative to explain Personalisation Engine and Learning environment, changed terminology and added a linking arrow between elements.
Issue	Thought I would put this up for discussion. I ended up doing a use case without AI as an actor because it didn't need to be. What if the entire LE has smart functionality, as stored user data and made decisions within the platform without an other actors interfering? What if a CD and COP only added to the repository? So was able to elevate the experience by providing more resources for AI to read from? I think this is a good start but could be expanded upon. Especially if [C4] has her own ideas coming out of the research she has done. Let me know of your thoughts. [12 *comments followed*]	Added platform connected through an xAPI which can be initiated by students.

While in most cases each team member worked on a particular model, when others provided in-depth feedback they included an example model and code in their comment, rather than in the document itself. As knowledge object updates often incorporated multiple sources of feedback, it was difficult to identify which of these were the specific source of a particular model modification. Team C generally waited until active team members had provided feedback and reached shared agreement on a way forward before committing their changes.

5.13.2. Components.md

Team C’s *Components.md* knowledge object was edited by multiple team members and continued to evolve over time, although there were fewer changes overall to this document than to *Use-cases.md* once the models had been drafted and initial feedback responded to. Figure 62 shows the development trajectory of *Components.md*.



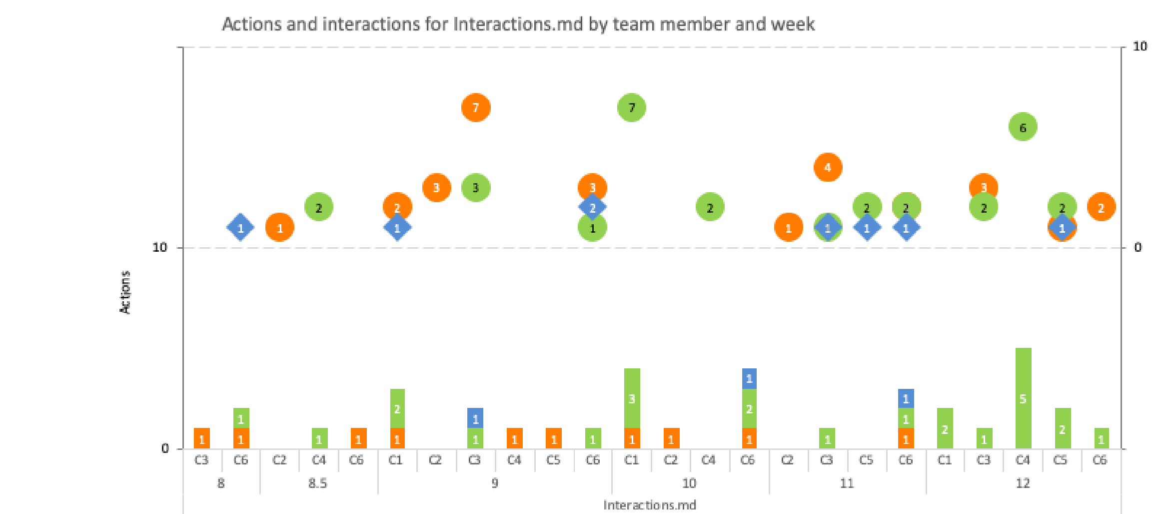
Week	7				8		8.5				9				10				11					12				
Member	C1	C2	C3	C6	C2	C3	C2	C3	C4	C6	C2	C3	C5	C6	C1	C4	C5	C6	C2	C3	C4	C5	C6	C2	C3	C4	C5	C6
Issue - KA													1	1					1				1			1		
Commit - KA						1						2		1				2		1		2		1	2		2	2
Comment - KP	1	1	1	1		1		1		1	1	1				1							1					
Comment - KA			1		2			1						1														
Comment - other			1		1		1				1	2						1	2	6	1	1	3		5	3	1	2
Commit - other								1	1			3	4		1		1	1		5		7	3		15	4	1	7
Issue - other						1						1	1					1		1		3					1	1

Figure 62: Knowledge object advancement and productive interactions for Components.md by team member and week.

This document also had a large number of minor edits, potentially because of the multiple authors, to establish consistent terminology and style before task submission.

5.13.3. Interactions.md

As the *Interactions.md* was the third task assigned by the instructor, students were more familiar with the GitHub system and UML modelling. Models were more sophisticated in their initial drafting, and feedback was then more targeted on specific features. Increased GitHub capability was visible in the same issue in the comment “omg omg omg this looks amazing!!! Why does this have conflicts to merge? Who's gonna solve them?”, indicating familiarity with the concept of merge conflicts and shared understanding of how to resolve them. The high number of comments not leading to changes in the knowledge object were predominantly positive feedback, thanks, general agreement, regulative and relational notes. Figure 63 shows the development trajectory of *Interactions.md*.



Teaching Week	8		8.5			9						10				11				12				
	C3	C6	C2	C4	C6	C1	C2	C3	C4	C5	C6	C1	C2	C4	C6	C2	C3	C5	C6	C1	C3	C4	C5	C6
Issue - KP								1							1				1					
Commit - KA		1		1		2		1			1	3			2		1		1	2	1	5	2	1
Comment - KP	1	1			1	1			1	1		1	1		1				1					
Comment - other			1			2	3	7			3					1	4		2		3		1	2
Commit - other				2				3			1	7		2			1	2	2		2	6	2	
Issue - other		1				1					2						1	1	1				1	

Figure 63: Knowledge object advancement and productive interactions for Interactions.md by team member and week.

While draft models were usually created by individual participants, all participants edited the drafts for terminology and presentation, for example, there were a large number of edits attempting to make the model images display correctly inline. As with the other knowledge objects, the data shows robust discussion around the model elements and the way they interact with the other artefacts, particularly *Use-cases.md*.

5.13.4. README.md

The *README.md* data showed instances of Team C testing new ideas, for example, C4 adds a line of code which in other contexts provides colour-coding of prompts. While it is not effective in Markdown (as Markdown is just a text structuring format), it is indicative of an exploratory approach. The data also showed considered decision making when discussing terminology, referencing definitions of the terms under consideration to support their agreement with the proposed change. Figure 64 shows the development trajectory of *README.md*.

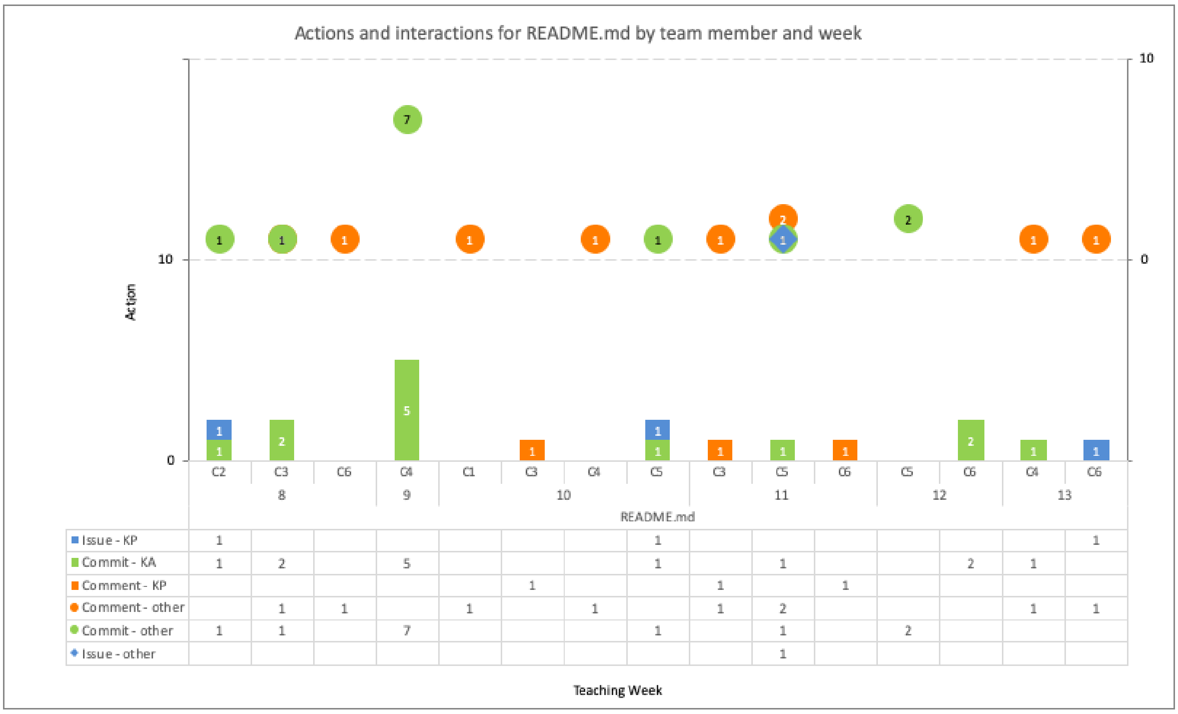
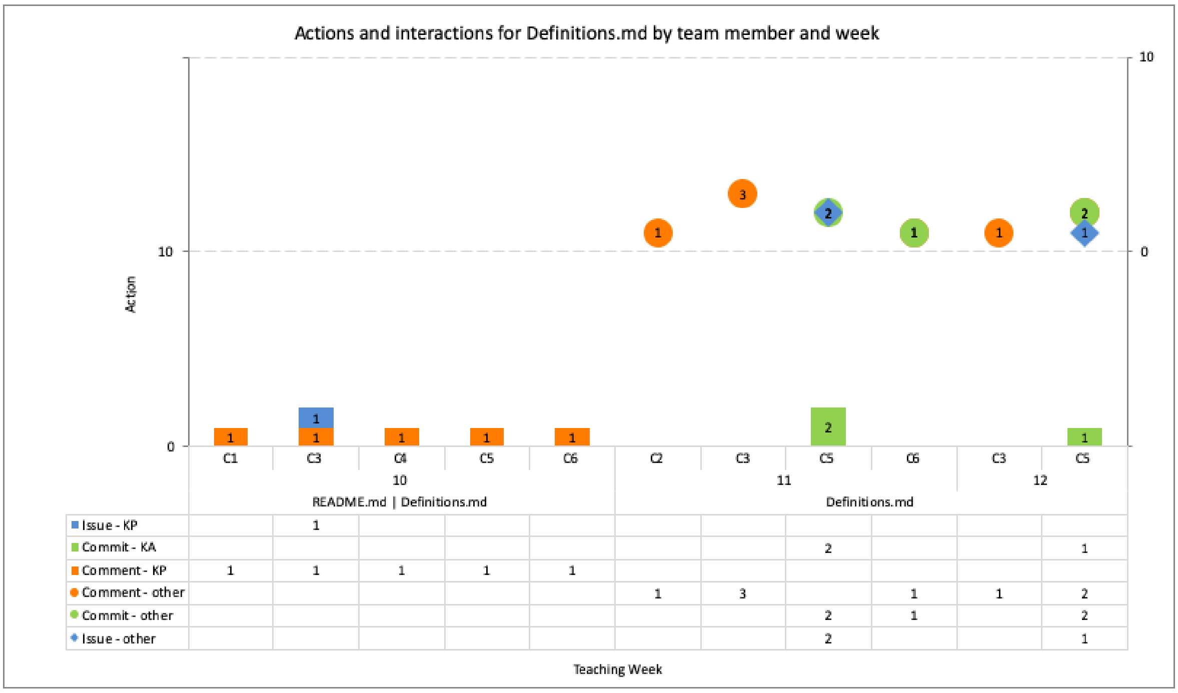


Figure 64: Knowledge object advancement and productive interactions for README.md by team member and week.

As a dynamic document representing the current state of the repo, changes that were made did not necessarily persist until task completion. Team C updated their repo less frequently than Team B, and moved wordy descriptions about their conceptual foundations to an intermediate object, *Defintions.md*, which is discussed in the next section.

5.13.5. Definitions.md

The team discussed whether to proceed with a meeting outcome to add a glossary of components to the *README.md*, deciding to make it a separate document linked from the *README*. They create the document at Week 8, moving the detailed descriptions out of *README* in Week 9, with one edit for content and some minor edits for style. There is then negotiation around the inclusion of a model diagram, which the team had agreed should not be part of the *README*. The participant who had suggested adding it to the *README* had added it in to Definitions.md with the comment “Added [C2’s] Adaptive LD diagram. I feel it helps to demonstrate the description above. I know there was feedback that it would be too much for the README however, this page is an explanatory page and I do feel it is beneficial to have visual representation. Happy to remove if no one else agrees.”, a departure from the team’s usual shared decision making process. The team agrees to leave it in place as “visual aids are always helpful and since this is not a mandatory repo required by management, we can design it in freer way.”. Figure 65 shows the development trajectory of *Definitions.md*.



Teaching Week	10 C1	10 C3	10 C4	10 C5	10 C6	11 C2	11 C3	11 C5	11 C6	12 C3	12 C5
	README.md | Definitions.md					Definitions.md					
Issue - KP		1									
Commit - KA								2			1
Comment - KP	1	1	1	1	1						
Comment - other						1	3		1	1	2
Commit - other								2	1		2
Issue - other								2			1

Figure 65: : Knowledge object advancement and productive interactions for Definitions.md by team member and week.

5.13.6. Summary

It was clear from the GitHub data that Team C made shared decisions about knowledge objects, and about the project direction and scope as a whole, and engaged in sustained efforts over time illustrated by their frequent productive interactions at Figure 66.

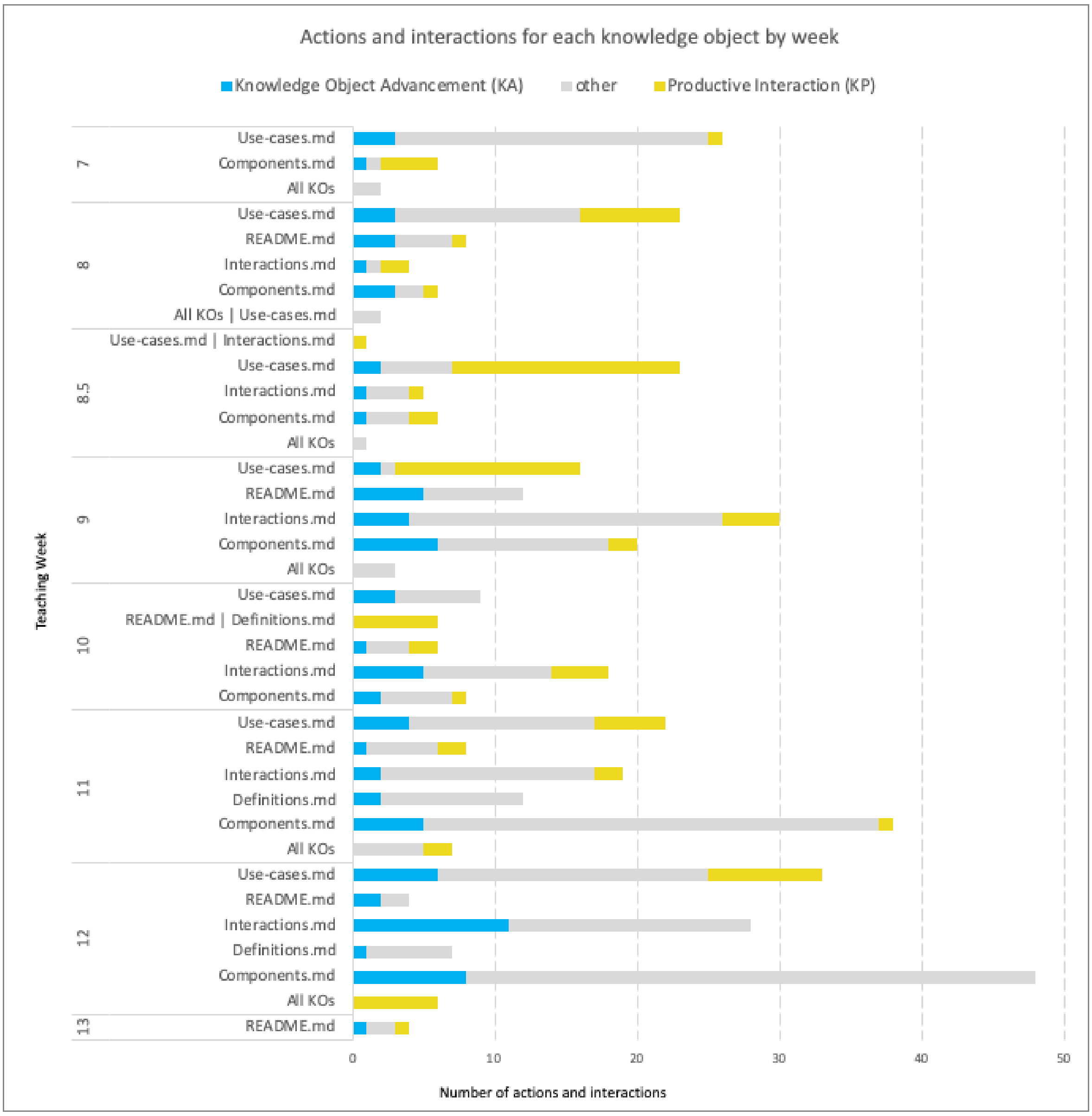
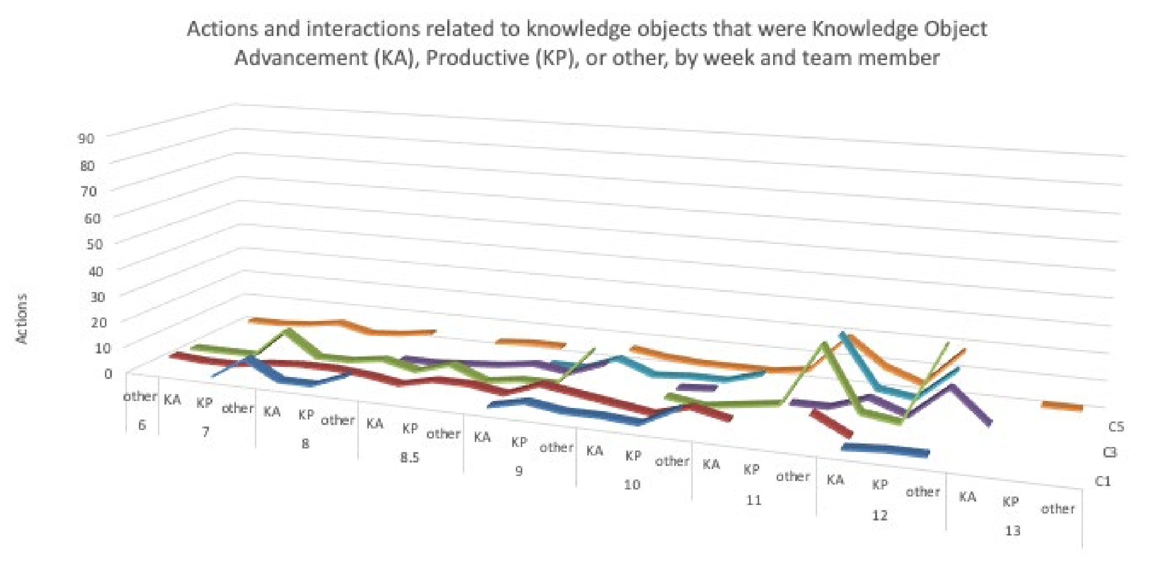


Figure 66: Summary of the productivity of knowledge object-related actions by week.

Their discussions about using use cases as the foundation for other models flowed through to create an integrated set of knowledge objects which made sense in relation to each other. It was also clear that meetings were regularly used to make decisions about their way forward, at both a conceptual and detailed level.

While model creation was usually done by individuals, the data shows the development was collaborative and involved sustained advancement over time in response to feedback and unspecified insights or inspiration. There is evidence of sustained engagement with all knowledge objects at group level over the course of the project and a relational component to their interactions. Team C also actively developed an additional knowledge object to add theoretical depth to their work while at the same time following the task requirements. A breakdown of individual contributions is at Figure 67 below.



	6	7			8			8.5			9			10			11			12			13		
	other	KA	KP	other	KA	KP	other	KA	KP	other	KA	KP	other	KA	KP	other	KA	KP	other	KA	KP	other	KA	KP	other
C1	1		1	9	2	2	7		5		2	5	3	3	2	9		1		2	3	3			
C2	2	1	1	3	4	4	3	1	4	4	2	7	5	3	1	5	2		8	1		3			
C3	1	1	1	12	3	3	5	2	6	1	3	3	17		3	1	3	5	28	5	3	32			
C4		1		1			1	1	2	3	5	3	8		2	3		1	1	6	1	13	1		1
C5											1	1	6	1	2	2	6		24	5	3	15			
C6	1	1	2	4	1	2	4		3	4	4		6	4	3	3	3	5	19	9	4	18		1	1

Week and productivity of action, by team member C1 C2 C3 C4 C5 C6

Figure 67: Knowledge Object Advancements, Productive Interactions and interactions and actions that were neither but related to Team C's knowledge objects by team member and week.

6. Discussion

This chapter provides commentary on the results presented in Chapter 5 as they relate to the aims of the research questions, the Literature Review, and the Theoretical Framework. It also reflects on how the research questions and results might be considered together to provide further insight into the development of agency in project-based group work at university and how educational design approaches can facilitate its emergence. Section 6.1 discusses the results in relation to individual and group agency, and Section 6.2 the emergent theme of relational presence. Section 6.3 considers the support GitHub can offer for knowledge building pedagogies, and makes some recommendations for task and environment design. Section 6.4 suggests some opportunities for using GitHub interaction data in collaboration research.

6.1. Individual and group agency

While previous studies have used micro-level interactional analysis of multiple data sources to classify individual agentic activity in relation to broader shared interactions (Damşa, 2014; Damşa et al., 2010; Damşa & Ludvigsen, 2016), this study has demonstrated that it is possible to classify activity at the level of discrete individual, asynchronous actions such as creating a GitHub Issue to ask a question or seek feedback (Sections 5.2—5.5). The frequency of each interaction type can be established to construct conjectures around the predominant characteristics of each group's collaboration (Sections 5.6 and 5.9) which have a high level of validity (Section 5.8) when compared with analysis of self-reported activity (Section 5.7). The identification of agentic activity further demonstrates that professional knowledge environments such as GitHub support collaborative conditions under which agency at multiple levels can emerge (Section 5.1).

Research on collaborative agency has historically focused on joint actions (Koschmann & Schwarz, 2021), with individual communicative acts rejected as possible units of analysis of educational dialogue (Baker et al., 2021) because of the sociocultural view of knowledge as necessarily shared (Stahl & Hakkarainen, 2021). However, establishing an association between the level and extent of individual participation and joint productive interactions provides insight into the role they play in relation to the way the group regulates their work (Isohätälä et al., 2017; Panadero & Järvelä, 2015) and allows investigation into the interactions of these levels

(Stahl & Hakkarainen, 2021). From a practical point of view, initial coding of actions at individual level is also necessary to construct trajectory or network analyses or other accounts of educational dialogue, and although individual actions are inextricable from their shared context in group work, it is important to establish connections between the different types and levels of data (Baker et al., 2021; Paavola & Hakkarainen, 2021).

6.1.1. Differences between individuals

The findings from this study indicate a relationship between team member participation, frequency and type of interactions at an individual level, and the group's level of object-related productive interactions sustained over time (Sections 5.10—5.13). This shows that individual agency makes an important contribution to group practices (Section 5.14). This result is logical, but also reflects the tension in socioculturally-based CSCL because the individuals are inextricably embedded in that specific group context (Stahl & Hakkarainen, 2021) and the group itself a complex system with unique characteristics (Fischer et al., 2018; Hmelo-Silver & Jeong, 2021b), making generalisation of any result difficult. The findings are consistent with previous studies finding different levels and types of contribution within (Damşa, 2014; Oshima et al., 2015, 2018) and across teams (Damşa et al., 2010; Damşa & Ludvigsen, 2016). The results are also similar to Oshima et al. (2015, 2018) social network analysis of a discourse dataset of university students engaged in collaborative problem solving, with participants' epistemic contribution patterns individualised and fairly stable; team members who contributed frequently did so over the course of the project, and those who contributed less also did so over the whole project, with the exception of the 'tidying' activity prior to task submission. This minor difference might be understood in relation to their setting of four sessions of synchronous discussion (Oshima et al., 2015) rather than this study set in a long-term project-based task iteratively developing modelled knowledge objects online. The finding also indicates that groups did not generate increased participation by less-engaged team members over time through strategies that were not visible in the GitHub data.

While encouraging contribution from all participants is sometimes addressed by using formal collaboration scripts (Fischer et al., 2013; Reimann, 2018; Vogel et al., 2021; Wise & Schwarz, 2017) that structure group regulation through either instructor intervention or explicit instructions (Dillenbourg, 2002; Fischer et al., 2013), this approach can inhibit the development of agency (Dillenbourg, 2002; Scardamalia, 2002; Schwartz & Okita, 2004; Wise & Schwarz, 2017) and often add increased teaching load (Dillenbourg, 2002; Wise & Schwarz, 2017). Classroom orchestration approaches have similar constraints (Wise & Schwarz, 2017), although emerging technologies such as dashboards generated from learner data can simplify flexible responses (Amarasinghe et al., 2021; Wise & Schwarz, 2017). However these are most frequently used in face-to-face synchronous collaboration settings with the instructor present and involved (Amarasinghe et al., 2021; Han et al., 2021).

The scripting and orchestration approaches view participation as an aspect of self- and co-regulation that can be approached by providing scaffolding for contributing to collaborative activities. Regulation is conceptualised as active engagement in planning learning, monitoring performance and dealing with challenges that arise in relation to the learning tasks (Hadwin et al., 2018; Järvelä & Hadwin, 2013; Järvelä et al., 2018), and has substantial crossover with ideas of agency, without the granularity of classification into multiple epistemic and regulative categories. Regulation can operate at individual, collective and shared levels, can create the conditions for agency, particularly over time (Järvelä et al., 2018), but also assumes agency in its conduct (Hadwin et al., 2018). There was an element of scripting in this study, as each group created a meeting roster and plan for contributing in the first weeks of the project using scaffolding materials provided in their repo. The different appropriation and modification of the templates by each team indicates their use as macro-scripts (Tchounikine, 2019), creating a "high-level didactical contract with the teachers' objective" (Wise & Schwarz, 2017, p. 431) rather than micro-scripts prescribing specific individual actions (Wise & Schwarz, 2017). The results show an association between the explicit collaborative aim of the groups in their plans for working together with the frequency and nature of contributions over time, supporting the proposition that guidance and constraint while allowing choice can enhance agency and support self-, co-, and socially shared regulation (Wise & Schwarz, 2017).

Complex, meaningful, project-based tasks with opportunities for leaners to exercise choice about the way they work and reflect on their learning are optimal for facilitating regulation in learning (Hadwin et al., 2018; Järvelä et al., 2018; Jeong & Hmelo-Silver, 2016), as well as the foundation of knowledge building (Scardamalia, 2002; Scardamalia et al., 2012; Tan et al., 2021) and trialogical learning (Hakkarainen et al., 2006; Paavola & Hakkarainen, 2014;

Paavola et al., 2011). This study shows that individual group members engaged with the authentic, ill-structured task and negotiated team processes in different ways, demonstrating different aspects of agency. In one team, this is illustrated by a particular team member seeking specific instructor guidance while others are moving forward with the task, in another by a team member's use of PowerPoint™ in preference to the specified tools and notation for the task, and in another by a team member circumventing the team's agreed workflow processes and modifying negotiated terminology. This difference between individuals' contributions reinforces that regulation is a complex phenomenon situated in personal experiences, ontologies and epistemologies interacting with cognitive, social, emotional, motivational and contextual variables (Hadwin et al., 2018; Järvelä & Hadwin, 2013; Järvelä et al., 2018) and an understanding about all those conditions for each individual is necessary to inform research (Järvelä et al., 2018). However, contemporary research on emotional and motivation regulation, particularly socially shared regulation, is still gathering evidence to inform guidance (Järvenoja et al., 2017), and directed toward multimodal and physiological data collection (Isohätälä et al., 2021; Järvelä et al., 2021; Saint et al., 2022), which has implications for learner privacy (Schneider et al., 2021) and challenges in practical implementation for mainstream higher education. To successfully develop epistemic agency, groups need to balance epistemic and regulative activity (Damşa et al., 2010), and too much emphasis on the social aspects of collaboration can inhibit knowledge building (Isohätälä et al., 2020). A finding from this study which is relevant to the social aspect of collaboration for the student groups is the association between relational presence in communication and the level and nature of interactions, discussed further at Section 6.2 below.

More recently, CSCL research has investigated how technologies foregrounding social awareness of other team members can support participation in group work (Bodemer et al., 2018; Buder et al., 2021; Crook, 2022; Schnaubert & Bodemer, 2022). While some findings have indicated that awareness of individual contributions can improve participation rates (Buder et al., 2021), results are inconsistent (Strauß & Rummel, 2021) and there is mixed evidence of positive impact of group awareness on learning outcomes (Bodemer et al., 2018; Buder et al., 2021). The social and group awareness approaches view participation as coupled with the development of metacognition (Buder et al., 2021; Järvelä et al., 2018), and emphasise the social and motivational experience of students as well as their cognitive progress (Hadwin et al., 2018). Through conscious monitoring of individual and group cognitive and task processes, teams can improve their experience of collaboration as well as their individual and group learning outcomes (Isohätälä et al., 2021; Järvelä et al., 2021). However, the increased participation, regulation and productivity that is possible through metacognitive monitoring (Isohätälä et al., 2020) also requires continued attention to the socio-emotional state of each individual and the group as a whole (Isohätälä et al., 2017; Strauß & Rummel, 2021), and, specifically, *sensitivity* to conflict, ego, power, tensions and emotion (Isohätälä et al., 2021). Individual differences between perceptions, life experiences and skills influence behaviour (Isohätälä et al., 2021), and CSCL environments may introduce barriers to constructive and respectful collaboration (Isohätälä et al., 2021). The way in which group members react to the contributions of others can influence their willingness to participate and the nature of their engagement (Järvelä et al., 2021), leading to unproductive behaviour such as social loafing (Isohätälä et al., 2020). The GitHub environment offers some visibility on the productivity of others in a group measured as volume and timing of contributions, and supports social awareness through the shared communication and workflow tools. Suggestions for its use by instructors, learners and researchers to support social visibility are discussed in Sections 6.3.6 and 6.4.1. In this study, the way in which team members monitored their colleagues' engagement with the team and task was different between groups, discussed further at Section 6.1.2.

Although there is an argument that because participation is not always related to student satisfaction (Gasell et al., 2021), equal contribution should be questioned as a goal for collaborative groups (Strauß & Rummel, 2021), unequal participation also influences the learning outcomes for both individuals and groups, with fewer diverse perspectives available as well as unevenly distributed epistemic, regulative and productional loads (Isohätälä et al., 2020; Strauß & Rummel, 2021). The group may respond to uneven contributions according to their perception of both the specific team member and the reason for their behaviour, either increasing their efforts to compensate, or reducing their contributions to match (Strauß & Rummel, 2021). All teams had some degree of imbalance in activity between team members in this study, which as well as the complex individual socio-emotional -motivational factors discussed above, could simply be related to different personal priorities (Järvelä & Järvenoja, 2011). Team A had the fewest team members, and these perceptions of others may have been why the remaining members did not generate additional activity either when other students withdrew from the course or when some agreed contributions were absent or inadequate, in contrast to Group A in Damşa et al. (2010), which responded to a similar situation with a joint discussion leading to production of a shared, useful, knowledge object. Without individual participation and interaction a sense of community is less likely to evolve and epistemic effort is less likely to be sustained (Zhang et al., 2009), which is visible through the indirect nature of Team A's communications with each other and productional activity around task completion. Section 6.3.6 sets out recommendations for design to scaffold more participation and contributions across both epistemic and regulative dimensions.

6.1.2. Differences between groups

The analysis results are consistent with the findings of thematic studies on the development of shared epistemic agency (Damşa, 2014; Damşa et al., 2010; Damşa & Ludvigsen, 2016) and group modelling (Richter et al., 2012) in higher education project-based group work, with differences between student teams in their general manner of working together visible through specific categories of epistemic and regulative activity despite working on the same task in the same designed collaborative environment.

6.1.2.1. Epistemic dimension

Teams differed in the way they created awareness, alleviated a lack of knowledge, created shared understanding and engaged in generative collaborative actions, both in relation to the task and the environment. Specifically, they engaged in different epistemic behaviours, and had different approaches to seeking and responding to feedback.

Awareness/knowledge

In Team A, there was little discussion around the aims and goals of the task, or the theoretical approach that might be appropriate. Requests for input from others were indirectly phrased, for example "struggling with" in a Commit comment as an explanation for why work was incomplete. There were few requests for help and fewer responses. It was rare that people were asked what they thought, with the exception of the deliberate design critique. There was some 'playing down' of work required: "<u>just</u> need an agenda", "<u>just</u> a description … academic spin", "<u>Just</u> a thought", which might indicate a limited scope both of understanding and for responses. For example, in the "struggling" Commit above, the comment is focused on the incomplete work rather than the incomplete understanding. The response, while personal, is also focused on production rather than understanding. When the technical barrier of UML was overcome, the learner still didn't know where in the document set it belonged, and their celebration "I finally figured out how to create a simple UML diagram" was not met with praise or encouragement, or direction to where the diagram might belong, simply an immediate merge to the master branch. The absence of interactions that built on the requests for help or ideas of others may have led to fewer positive socio-emotional interactions and thus a lower level of regulation (Isohätälä et al., 2020).

While Team A collected additional information in the form of reading summaries, it's not clear that this was used in their knowledge objects. Strauß and Rummel (2021) proposes that a reduction in participation in joint work can arise where group members feel the 'norms' of collaboration have been violated to their disadvantage. This may be relevant for this team as the reduction in group membership through student withdrawal was unexpected. Another explanation could be that the dominance of one team member's perception of the task may have violated the norms of those who expected a more mutual collaboration and negotiated epistemic goal, leading to reduced effectiveness of the pedagogical design for collective cognitive responsibility (Scardamalia, 2002; Zhang et al., 2009). Without the joint creation of awareness about the knowledge required to address the group's task, epistemic agency is unlikely to emerge (Damşa et al., 2010).

Team B asked more direct questions to each other about their environment, and provided more specific information to others about how to use it in Commit comments and Issues. When one team member expressed doubts about what they were meant to do (on more than one occasion), their question was responded to by another in contrast with help-seeking actions in Team A. Team B also engaged in some in-depth discussion around underpinning concepts such as 'learning styles', again achieving input from multiple team members. However, in several cases where changes were made to knowledge objects that were destructive, the participant does not ask others for help and simply engages in ineffectual trial and error document modification until another team member resolves the problem just prior to task submission. Team B explicitly sought information on pedagogical research and all team members contributed in some way, from simply posting citations through to summarising the key points and relevance to their project. However, it's not clear how these were used in relation to their knowledge objects as the knowledge objects were developed first. These results indicate that the group realises the importance of creating shared understanding in relation to the task (Damşa, 2014), but may have differing ideas about the level of academic performance that is appropriate within the team or the project, again reflecting different priorities. This makes it less likely that the cognitive activity generating new knowledge creation will arise (Järvelä et al., 2021). Although one explanation is that student goal orientation is variable, with some students focused on the behaviour of task completion rather than learning or knowledge building (Bereiter, 2002a), the lack of attention to quality and completeness may mean it is more likely the students considered the work not as authentic products in the appropriate learning domain, but a 'school' activity that had no intrinsic meaning (Brown et al., 1989; Strauß & Rummel, 2021). This inference is also relevant to the work of Team A.

Team C also asked direct questions about GitHub, the goals and parameters of the task, and the modelling environment, which were responded to by others. Responses sometimes included diagram and code examples, and where it was felt that a question hadn't been sufficient addressed, the discussion continued, for example, "Actually, I was thinking more broadly…". Help-seeking actions were mixed, with one team member preferred to ask the instructor directly for help and information, where another searched "online, reference guides, cheat sheets" before asking another team member for assistance. When a particular model version was difficult to locate, the discussion around which it was and how to reinstate it was conducted in an Issue, resulting in a resource which could be re-used by the team. Similarly, when the instructor provided scaffolding (to all teams) around model types, the team appropriated the response as a persistent reference over the course of the project. In contrast with Teams A and B, Team C's high rate of epistemic activity in creating awareness and alleviating lack of knowledge suggested a personal and meaningful connection with the concepts indicated an intention to learn what is being taught rather than simply complete the task (Bereiter, 2002a) and to mobilise the knowledge within the team toward an exploration of what might be possible. The results showed negotiation of meaning through shared attention to the knowledge component of the task, leading to cognitive change (Bransford et al., 2000; Dillenbourg, 1999; Johnson & Johnson, 1996) and new knowledge being created.

Shared understanding/generative collaborative actions

Team A's interactions indicated the absence of a feedback mechanism around the knowledge objects, and an absence of discussion around their iterative development and content. While a team member provided a template that was used for design critique, no model was modified in response to the suggestions made using the template, nor was there discussion following the in-class knowledge exchange activity in Week 12. There was also little intra -group knowledge exchange, for example one team member added a comment containing use-case diagrams but the development of them is not discussed in GitHub or in the Minutes. Yet both the code and the structure are useful resources for others in the team. There is little evidence of any advancement of each knowledge object once the first draft has been prepared, except for 'tidying' in relation to structure and format. Contributions that didn't meet the task requirements didn't generate any visible discussion. In one case another participant simply re-created the work without discussing how it was done, and in another the participant replaces their model with another, again without discussion of why/how it is different and the process by which it was changed. There's a sense with Team A that once artefacts are created nobody looks at them again, or talks about them at all. This is an approach aligned with cooperation (Dillenbourg, 1999) or coordination (Engeström, 2008). It might reflect a perception by the group that as they had fewer members they had fewer resources to apply in a feedback process. Alternatively, it could indicate that group members were not open to reconsidering their ideas (Damşa et al., 2010), which could also be relevant to the findings of Team B.

Team B had an agreed feedback mechanism, but not all team members engaged with it. A specific feature of this team's work was the language around feedback, with most requests not seeking a discussion around the ideas, but instead to simply "feel free to amend it" or "feel free to scrap it". Team B opened multiple Issues for the same knowledge object, leading to confusion around where feedback was located. It was clear that some participants did not read the previous Issue and comment feedback prior to making changes to the knowledge objects, and while feedback was provided to team members by others on multiple occasions for multiple knowledge objects, it was rarely incorporated in a knowledge object by the original author even when they had explicitly said they would do so. Team B appeared to have a performative approach to seeking feedback, and did not persist in improving their knowledge objects over time except to remedy errors. The results showed a reluctance by team members to engage in negotiation that resulted in consequential change. This is similar to Damşa and Ludvigsen (2016)'s description of a *discourse-oriented* collaboration, where the group engages in dialogue aimed at joint understanding, but do not materialise this elaboration into knowledge objects, perhaps reflecting less individual and shared cognitive responsibility for understanding the way in which their knowledge objects were developing in relation to the task requirements. Zhang et al. (2009) found that cognitive responsibility could be improved in a knowledge building community over time through opportunistic collaboration with dynamic instead of static group composition, however, their three-year timeframe is difficult to replicate in higher education project work and outside a traditional classroom setting. Their study also showed promising results in cross-group collaboration (Zhang et al., 2009), designed for in our Week 12 knowledge exchange, which is potentially a better fit for our context.

Team C generally waited until all regularly-participating team members had contributed feedback, clarifying and negotiating meaning, and acting on the feedback received. When they received further information from the instructor in relation to the role of AI they made changes to their modelling in response, and were the only team to act on the feedback generated by the design critique task, and to change their approval process in response to the process reflection task. Feedback within the team resulted in discussion about where the ideas might be incorporated in other knowledge objects, and how changes might impact the relationship between the different models. As well as clarifying questions and remedial suggestions, Team C provided consistent positive reinforcement and praise to each other through comments like "Great sequence diagram…" and "Wow this looks amazing!". Having a defined workflow process requiring others to approve is likely to have contributed to this feedback approach, but the epistemic team interactions show the participants wanting to make sense of their knowledge objects at a deep level, and for them to reflect a sophisticated and integrated system. This indicates an awareness of the value of multiple perspectives, and of feedback as an epistemic input associated with the potential for knowledge development (Damşa et al., 2010). While peer feedback can be a useful process in collaborative learning (Jeong & Hmelo-Silver, 2016), students can struggle to provide high-quality feedback without scaffolding (Kollar et al., 2018). While individuals from Teams A and C created intermediate knowledge objects for self-critique of their models, neither they nor Team C constructed a specific model for the structure of feedback within the team. However, Team C's workflow process resulted in feedback from individuals being provided in a structured way using Issues and Pull Requests.

6.1.2.2. Regulative dimension

Team A did not appear to have a collective commitment to either the process or the product, with repeated questions continuing through the course of the project and a reluctance to contribute more than was essential to task completion. One team member took a leadership stance, asking for confirmation that work they had assigned to others was complete without monitoring the quality of the work, but asking a different team member to the one to which the work was assigned, talking <u>about</u> a team member without talking <u>to</u> them. There are multiple instances where a lack of communication is associated with a lack of progress on their project. Together with the lower level of epistemic activity discussed above, there is a sense that the only thing that is important is meeting the task requirements. Not exceeding, bending, creatively flouting or renegotiating them, but minimal effort (Bereiter, 2002a), *satisficing* (Simon, 1957) them. Simon describes this as a rational choice as to what constitutes a "good enough" (p. 203) course of action instead of the best option. This simplifies the process of identifying and choosing between available options (Simon, 1957) and requires only minimal comprehension that is sufficient to address the task (Bereiter, 2002a). This reduces cognitive effort (Simon, 1957), but is ineffective at integrating new information with prior knowledge (Bereiter, 2002a) and indicates mastery is not the goal. Differing goals and perceptions of participation affect the regulation process (Strauß & Rummel, 2021) and this is visible in the differing efforts made by individuals within each team, and consequently differing team characteristics.

A factor which may have impacted Team A's regulation is the number of participants. There is mixed opinion on optimal group size (Almajed, 2015; Smith et al., 1992), with Johnson and Johnson (1999) recommending two to four members, and other authors suggesting it is important to find a balance between a larger number of members in order to gather more collective information and a small enough group to reduce cognitive load (Janssen & Kirschner, 2020). On the other hand, fewer group members makes regulation simpler (Jeong & Hmelo-Silver, 2016). Another factor could be team formation, as in this study, groups were formed randomly, rather than on friendship (Damşa & Ludvigsen, 2016) or interest groups (Damşa, 2014; Damşa & Ludvigsen, 2016) which have potential to offset difficult social dynamics (Almajed, 2015).

The results of this study show different approaches to leadership around regulation within each team. Leadership is also a consistent concern in higher education group work, and single directive-only leadership such as that visible in Team A's regulative actions can have negative effects (Almajed, 2015). Taking joint responsibility for sharing it is an important part of knowledge building pedagogy (Tan et al., 2021) and this was scaffolded in the study through support for rotating group roles if the students chose to use them. Where Teams B and C used these supports, Team A did not persist with them. Differences in dominance, power and status are part of the situated, contextual, complex phenomenon of regulation and participation (Isohätälä et al., 2021; Strauß & Rummel, 2021).

Team B had a slightly more concerted commitment to their project, and established a workflow process early on which is evident by comments like "happy for you to merge". However, this is not maintained over the course of the project. While not deferring to a specific team member as authoritative in the same manner as Team A, comments such as asking if the author has made "major mistakes" or are "wrong" give the sense that 'checking' their work is up to someone else, reflecting the tension around cognitive responsibility discussed above in relation to general collaborative actions. Not all team members contributed equally to knowledge object development, and like Team A, there are comments where another team member is named in relation to their unfinished work, but not tagged or visibly communicated with directly. The comment "I don't have any more time to devote to it" without a request for support or negotiated alternative gives a similar sense of *satisficing*, but it is not consistent across the whole team. Others in the group work in the background to repair this work and improve the quality of their shared product, perhaps because of individual characteristics such as conscientiousness (Strauß & Rummel, 2021) conceptualised as non-cognitive competence incorporating persistence, perfectionism, organization, and carefulness (Shute & Ventura, 2013). This could indicate they were aware of the imbalance in goal-directed activity but emphasised the socio-emotional aspects of the collaboration.

Team C engaged in a workflow process incorporating feedback that also monitored their knowledge object quality and development timeframes. This was maintained throughout the project. However, there was one team member who, like in Team B, bypassed the approval process and made changes to their knowledge objects just prior to task submission which were inconsistent with the broader team's intentions and reduced the knowledge object quality. As with Team B, Team C appeared to prioritise group harmony and did not either criticise the changes or revert them. These actions can be observed in GitHub data in a manner not found in traditional CSCL or SSRL analysis, and may be an example of when knowledge building activity is impacted by a focus on the social rather than epistemic or regulative aspects of collaboration (Isohätälä et al., 2020).

6.1.3. Shared epistemic agency

Team A demonstrated shared agency predominantly in relation to their regulative actions, with limited epistemic engagement at either individual or shared level. They have some similar characteristics to Group B in (Damşa et al., 2010), acting individually and informing each other of outcomes, with lower shared awareness of the state of the knowledge objects. The also manifested less sharedness generally, to the extent of having specific team member names in their documents as either placeholders for required work or evidence that individual work had been completed. Team B engaged in more discursive actions indicating shared epistemic agency than Team A, but had less consistent epistemic and regulative engagement and a lower frequency of knowledge object advancement than Team C, which was more similar to (Damşa et al., 2010) Group A in their combination of object-oriented epistemic and regulative activity. Although the purpose of co-constructing models for knowledge building was elaborated in lectures. there was some evidence in each team of one team member whose view was that the group should be provided with all the information that individuals need to proceed with the task without actually working together, perhaps reflecting the preference for individual work identified in (Cunningham et al., 2016) realised through vertical task division (Dillenbourg, 1999).

Team C is similar to (Damşa, 2014) Group D in that they engaged in collective discussion to understand and take up each other's' ideas through materialisation of knowledge then elaborated by others. Team B displayed some similarities to (Damşa, 2014) Group A, with agency evident in discursive interactions, but limited materialisation of concepts and ideas into iterative versions of knowledge objects. Team A is similar to (Damşa, 2014) Group B, focusing on a division of labour and finalisation of the task.

These results show a clear association between object-oriented epistemic and regulative interaction frequency and productive interactions that lead to concrete knowledge object advancement indicating the emergence of shared epistemic agency. There was also a positive relationship between the level of relational presence in team interactions and the number of productive interactions, discussed at Section 6.2.

6.1.4. Summary

The results show that individual and joint actions across the epistemic and regulative dimensions related to knowledge object advancement are visible in GitHub interaction data. The analysis supports previous findings that a shared approach to a balance of epistemic and regulative actions leads to a deeper elaboration of ideas and materialisation into knowledge objects (Damşa, 2014; Damşa & Ludvigsen, 2016).

The differences between teams are similar to those found in Damşa (2014); Damşa et al. (2010); Damşa and Ludvigsen (2016), with clear distinctions between groups with (a) more frequent generative epistemic actions (Group A in (Damşa et al., 2010), D and E in (Damşa, 2014), A in (Damşa & Ludvigsen, 2016)), (b) focus on individual contributions and task division (Group B in (Damşa et al., 2010), B in (Damşa, 2014), C in (Damşa & Ludvigsen, 2016)) and (c) one more groups in between (A and C in (Damşa, 2014), B in (Damşa & Ludvigsen, 2016)). This provides support for the empirical construct of shared epistemic agency and the framework developed by Damşa et al. (2010), and demonstrates that it can be observed in project-based group modelling work in higher education.

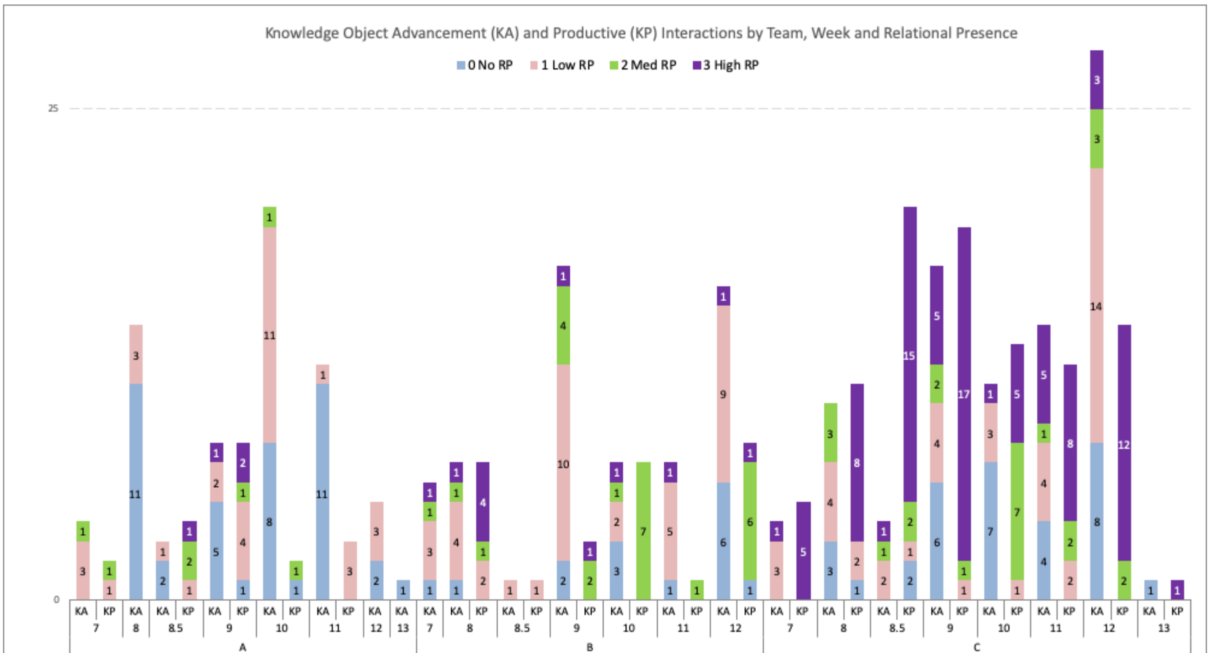
While Damşa (2014); Damşa et al. (2010); Damşa and Ludvigsen (2016) did not speculate on the reasons for the differences between groups, Damşa et al. (2010) identified the difficulty of drawing a clear boundary between individual and collective characteristics of shared epistemic agency. When extending their research to explore productive interactions, they found them characterised by individual input woven into joint efforts in relation to the knowledge objects (Damşa, 2014). Although research on group work frequently takes the group as the object of analysis (Damşa, 2014; Damşa et al., 2010; Damşa & Ludvigsen, 2016), given the capacity for GitHub data to provide deep insights on contribution at individual as well as collective levels, and the impact on the group product found in individual actions in this study, we might consider how more attention can be given to the role of individuals in the development of shared epistemic agency, and the way in which their approach to collaboration may influence these group differences.

This unequal distribution and quality of individual work reflects student concerns about equitable contribution and the fairness of grading. In this study, student participation was scaffolded through both pedagogical and technical affordances for shared development of group processes, negotiated decision making, and collective model co-construction, based on the evidence for the development of agency in studies using the trialogical framework for knowledge creation. The results show that while all the teams constructed artefacts describing collaborative processes with full participation, these did not always reflect how they worked in practice and there was little evidence of the use of any supplied resources other than the templates for meeting organisation. While Damşa (2014) provided scaffolding for self-organisation of activities, and Damşa et al. (2010); Damşa and Ludvigsen (2016) technological support, they do not report the nature or appropriation of these resources. While the way in which collaborative groups approach the process of developed shared knowledge objects is critical to the development of shared epistemic agency (Damşa et al., 2010; Damşa & Ludvigsen, 2016), the factors influencing each group's approach are not reported in this, or their, studies.

The findings from this study are consistent with the identification of particular interaction patterns present across other studies on shared epistemic agency (Damşa, 2014; Damşa et al., 2010; Damşa & Ludvigsen, 2016), characterised by the manner of their collaboration. Teams which engaged in epistemic and regulative activities demonstrated a type of agency contrasting with teams which engage in predominantly regulative activities, showing the importance of the way in which groups approach their process (Damşa et al., 2010). Teams which engaged in object-oriented activities demonstrated a type of agency contrasting with those engaging mainly in discourse (Damşa, 2014; Damşa & Ludvigsen, 2016). Teams which engaged in predominantly individual actions demonstrated agency contrasting with those engaging in collective activity (Damşa et al., 2010; Damşa & Ludvigsen, 2016). Teams which engaged in a balance of epistemic and regulative object-oriented collective interactions generated more productive and knowledge object advancement activity.

6.2. Emergent theme: relational presence

The results showed a substantial difference in the levels of relational presence between the groups (Sections 5.3.4, 5.4.4, 5.5.4 and Figure 25. There was a positive association between levels of relational presence and actions that were productive or advanced the knowledge objects as illustrated at Figure 68, with Team C having significantly higher instances of both, followed by more relational but fewer productive interactions for Team B, and more productive but fewer relational for Team A. This approach to communication was evident at both individual and group level (Sections 5.3.6, 5.4.6, 5.5.6). This demonstrates that metacommunicative analysis can be overlaid on the thematic and trajectory analyses investigating shared epistemic agency, providing limited insight into the socio-emotional behaviours of the team visible in the GitHub data.



A	KA 7	KP 7	KA 8	KA 8.5	KP 8.5	KA 9	KP 9	KA 10	KP 10	KA 11	KP 11	KA 12	KA 13
3 High RP					1	1	2						
2 Med RP	1	1			2		1	1	1				
1 Low RP	3	1	3	1	1	2	4	11		1	3	3	
0 No RP			11	2		5	1	8	1	11		2	1

B	KA 7	KA 8	KP 8	KA 8.5	KP 8.5	KA 9	KP 9	KA 10	KP 10	KA 11	KP 11	KA 12	KP 12
3 High RP	1	1	4			1	1	1		1		1	1
2 Med RP	1	1	1			4	2	1	7		1		6
1 Low RP	3	4	2	1	1	10		2		5		9	
0 No RP	1	1				2		3		1		6	1

C	KA 7	KP 7	KA 8	KP 8	KA 8.5	KP 8.5	KA 9	KP 9	KA 10	KP 10	KA 11	KP 11	KA 12	KP 12	KA 13	KP 13
3 High RP	1	5		8	1	15	5	17	1	5	5	8	3	12		1
2 Med RP			3		1	2	2	1		7	1	2	3	2		
1 Low RP	3		4	2	2	1	4	1	3	1	4	2	14			
0 No RP			3	1		2	6		7		4		8		1	

Figure 68: Relational presence across knowledge object advancement and productive interactions by team and week.

While Damşa et al. (2010) does not speculate on the reasons for different engagement in the sociocultural process of developing shared epistemic agency, and while the relational presence layer is not the focus of this study, the emerging interest in social sensitivity in CSCL seeks to understand how individuals and groups create constructive, respectful and cohesive collaborations (Isohätälä et al., 2021). The tentative framework adapted from Burgoon and Hale (1984) encompassing the themes of immediacy/affection, similarity/depth, receptivity/trust and dominance/control allows identification of efforts to understand the feelings and viewpoints of others, and to exercise intelligence in relation to social and behavioural norms, important not only for social sensitivity (Isohätälä et al., 2021), but also for self- and shared regulation for learning (Malmberg et al., 2022).

The findings indicate that the GitHub environment supports the development of relational presence through affordances that allow team members to compose and reflect on communications, and rich text and images, tagging, threaded discussions and workflow processes into their interactions, however, the provision of these affordances does not guarantee it will emerge. This is similar to studies of asynchronous discussion (Fehrman & Watson, 2021), where multiple factors have been found to influence social presence (Kreijns et al., 2022) with similar variation across individuals and groups (Walther, 1995, 2012). While there has been substantial research on the use of discussion forums in the context of argumentation over the past three decades (Andriessen & Baker, 2014), and studies show similar complexities around the relational content of interactions (Andriessen, 2006), there are few recent developments in understanding how interpersonal relations are enacted in asynchronous collaboration. Where studies have been conducted in knowledge building discussion forums in school education, the socio-emotional dimension of communication has been considered as a separate thematic category, rather than a metacommunicative layer adding to either epistemic or regulative interaction (Fu et al., 2016).

6.3. GitHub as a platform for knowledge building

The results show that the GitHub platform has affordances which support knowledge building pedagogies, trialogical learning, and the development of regulative and epistemic agency at individual and collective levels (Section 5.1.1 and 5.1.2). All learners participated in knowledge co-construction using the networked environment, and developed knowledge objects with varying degrees of collaborative sharedness (Section 5.9). While there were differences in the frequency and nature of contributions, students used Issues, Pull Requests, Commits and a range of comment types to ask questions, make contributions, and engage in communication at both content (Section 5.3-5.5) and relational levels (Section 6.2). Each team used the rich text editing and UML notation capability within GitHub Markdown format files to construct and reflect on their own collaborative processes as well as engage in and monitor asynchronous joint knowledge object development (Section 5.7). The persistent nature of interaction data allowed trajectories of activity to evolve, and productive interactions to occur leading to advancement of their shared work (Sections 5.10-5.14).

6.3.1. Technology-enabled environments for knowledge building

Using technology-enabled platforms to collaborative with asynchronous messaging in a discussion forum has a rich history in knowledge building, beginning with simple knowledge objects made by school students about their project-based task inquiries (Scardamalia et al., 1989), and developed through the increasingly sophisticated CSCL knowledge building environments discussed in Section 2.5 of the Literature Review. These have evolved from organised notes incorporating graphics and iconic classification with a keyword search function (Scardamalia et al., 1989) to include multiple views of multiple notes (Scardamalia, 2002), and now encompass multiple media formats, video annotation and visualisations of semantic profiles (Scardamalia & Bereiter, 2021).

Learning Management Systems used in schools and universities also generally offer an asynchronous discussion function which also allows rich text editing, but lack the capacity to synthesise ideas into more complex structures through linking and organising (Scardamalia & Bereiter, 2014b). Professional tools such as Studio5000 (Rockwell Automation, 2022) also support the shared development of complex knowledge structures and system design, but they lack affordances for trialogical learning such as co-construction of group processes, mutual negotiation of goals, and epistemic activity such as creating awareness of required knowledge and generating shared understanding. These tools are frequently expensive[11], have particular licensing and software compatibility requirements, and significant training and support load. Figure 69 shows these environment types along a continuum reflecting the support they provide for co-constructing knowledge objects containing complex information that can be the focus of object-oriented discourse. Where purely professional tools support more complex object development, they lack the affordances for epistemic and regulative activities that are designed in knowledge building settings, and where educational environments support interaction and conversation around knowledge objects, they lack affordances for representation of complex ideas.

[11] For example, while Studio5000 Rockwell Automation. (2022). *Studio 5000 design software | factorytalk*. https://www.rockwellautomation.com/en-us/products/software/factorytalk/designsuite/studio-5000.html Rockwell Automation. (2022). *Studio 5000 design software | factorytalk*. https://www.rockwellautomation.com/en-us/products/software/factorytalk/designsuite/studio-5000.html does not offer transparent pricing on its website, after creating an account and logging in the current pricing is around AUD$5000 per user annually for the product without any plugins or integrations, and the same amount per user annually for support and training.

affordances for co-constructing complex knowledge objects

low level ⟷ ***high level***

Traditional LMS eg, Canvas	*Knowledge Building Environment, eg, KPE*	*Professional Knowledge Environment, eg, GitHub*	*Professional Tool eg, Studio 5000 ®*
text-based discussion file upload	text-based discussion file upload linking and organising knowledge objects incorporation of rich media group process and reflection support tools for sketching and modelling	text -based discussion file upload linking and organising knowledge objects and interactions incorporation of rich text and media through Markdown group process and reflection support incorporation of parallel representations of complex system models iterative knowledge object versions transparent view of participation persistent view frequency and nature of contributions access through standard web browser	text -based commenting component libraries incorporation of multiple representations of complex system models security & licencing support

Figure 69: Relative affordances of knowledge environments for co-constructing complex objects of discourse.

6.3.2. Support for project-based group modelling work

The results of this study show that while constructing UML models in GitHub together can lead to the increased cognitive load observed by (de Jong et al., 2018; Linn et al., 2018), the modelling process also made visible the epistemic activity about the underlying concepts and relationships within the systems being modelled. In their interactions, team members indicated specific elements in the model to question whether, for example, the arrow was headed in the correct direction, and in some cases demonstrated shared epistemic agency by improving their models to a higher level suite which had internal coherence. This supports the potential of modelling to externalise and materialise ideas (Hakkarainen et al., 2006; Paavola & Hakkarainen, 2014; Paavola et al., 2011), provide a focus for the collaboration (Paavola & Hakkarainen, 2014; Ritella & Hakkarainen, 2012), and act as boundary objects (Star & Griesemer, 1989) in the group collaboration for knowledge creation as suggested at Section 2.7.2. Suthers et al. (2007) found that better learning outcomes are associated with technology-enabled environments which are able to make conceptual objects and relations explicit, and when interactions are supported by conceptual representations, and Section 2.7 of the Literature Review sets out the evidence for active construction of models in understanding and visualising complex phenomena.

The incorporation of systems models in knowledge objects in this way is an important extension to traditional asynchronous collaboration environments, as they are knowledge objects in their own right. While this is a broad definition applicable to multiple types of output from knowledge creation activity (Paavola et al., 2011) like an Otto's notebook or online database, models are knowledge objects that contain specific meaning in a standardised form, which can be directly compared, emulated and amalgamated. While natural human languages have structure, interpreting meaning is subtle and prone to error, even for humans. Mind maps capture a set of concepts without hierarchical relationships, and concept maps capture the relationships but have no particular form constraints. Formal model notation describes complex systems, but can be difficult for humans to read. Because UML uses a notation which is close to natural human language, the cognitive load associated with learning a modelling language is reduced for learners. However, the notation is specific enough to be read by machines as well as humans (understood as 'interoperability'), meaning the resulting knowledge object becomes a foundation on which human and non-human agents including technologies (Donald, 2004; Fischer, 2006; Hutchins, 1995, 2001) can develop new knowledge. Instead of being simply a 'picture', a UML model expresses elements and relationships in a notational form that is coherent and valid because invalid aspects are identified by the modelling syntax checker in the process of its construction. Figure 70 illustrates the spectrum of notational forms and their level of interoperability, with the shaded area showing how UML can transcend and include the notational forms traditionally used in educational settings.

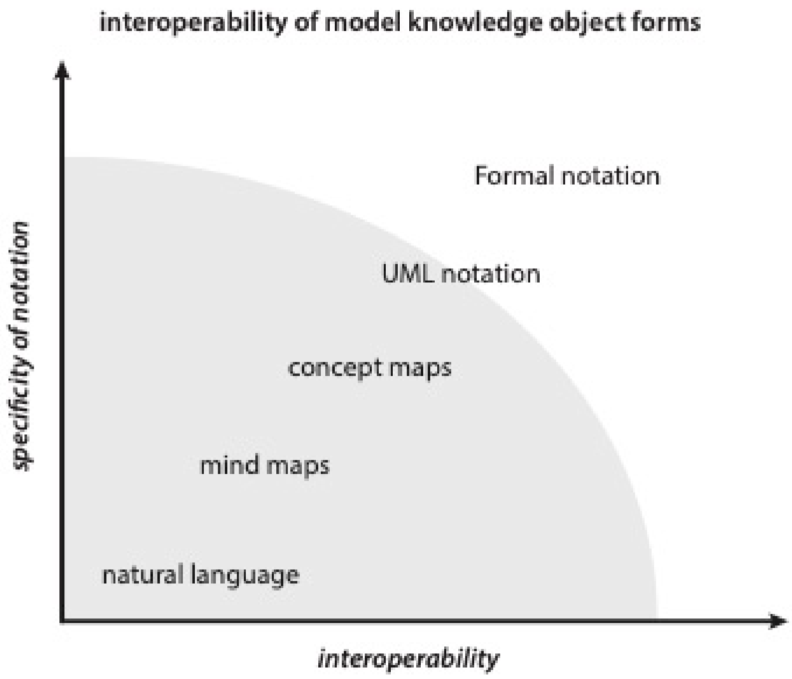


Figure 70: Combined levels of specificity and interoperability of knowledge object forms.

6.3.3. Support for object-oriented collaboration

The findings also show that using GitHub for asynchronous knowledge building is consistent with object-oriented collaboration principles and extends the opportunities for productive interactions through affordances for connecting discussion about knowledge objects with the objects themselves, which contain persistent traces of their advancement. Where other environments may implement a ‘bricolage’ of ad hoc tools (Rosé et al., 2019) GitHub contains native affordances for technology-mediated object-oriented collaboration in a single platform, with the capacity to embed parallel representations of complex knowledge objects and to collectively monitor group participation and knowledge object advancement.

While the focus of this study was on the emergence of agency rather than the use of specific GitHub affordances, the findings indicate that there is an association between the use of environment features such as Issues, Pull Requests and various types of comments, and productive interactions and knowledge object advancement. However, as teams developed their own processes for system use, causality can not be inferred. Use of the workflow tools for tagging, assigning and requesting was inconsistent across the groups. Development of knowledge objects in other branches before merging to master was also different from team to team. No mention is made in the data of using the views in GitHub to monitor individual or group contribution frequency and volume. The study design did not include specific instruction on these features or conceptual scaffolding for their use, although there are multiple freely-available online guides.

GitHub also more generally supports the knowledge building practices of sustained inquiry and continuous improvement, community dynamics and meta-discourse, and interdisciplinarity and extensibility (Tan et al., 2021), as well as offering the core CSCL affordances of facilitating engagement, communication, resource sharing, productive interactions, co-construction of knowledge, monitoring and regulating collaboration, and community development (Jeong & Hmelo-Silver, 2016). Each group used the platform features to iteratively develop multiple models and artefacts in their repos reflecting the state of knowledge within their team constructed through individual and group participation over time. Each team also constructed additional artefacts to capture a specific set of understanding, indicating real ideas were improved in an authentic task enabling epistemic agency, in some cases drawing on authoritative sources (Scardamalia, 2002). Teams used the environment features to engage in conversation about epistemic and regulative goals, processes and progress, with some teams using more sophisticated affordances to link these discussions to specific versions of a document or another thread of conversation, showing idea diversity, knowledge-building discourse, collective responsibility, democratisation of knowledge and rising above to higher level formulations of problems, (Scardamalia, 2002). While the task design, in-class instruction and in-repo conceptual and technical scaffolding resources were developed to facilitate frequent formative work including in-group self-assessment (Scardamalia, 2002), differences in the way groups approached the collaboration led to variation in symmetric knowledge advancement (Scardamalia, 2002). These differences are discussed at Section 6.1.2. The environment also supports a metacommunicative layer of relational interaction discussed at Section 6.2.

6.3.4. Good Issues

The findings of this study show the potential for GitHub Issues and Pull Requests to facilitate team discussions that are artefact-oriented and can be linked to specific versions of one or more knowledge objects. The incorporation of complex syntax and embedded diagrams allow expression of multiple layers of communication, and threaded comments keep related discussions together. Issues can foster awareness as they can be ‘followed’ in GitHub, team members tagged, and relevant knowledge objects and resources linked. While all teams used Issues in this way to some extent, there may be a limit to the number of concurrent Issues that is viable for efficient collaboration. We saw with Team B that with multiple Issues open for multiple documents it became complex and unmanageable leading to fewer perspectives being incorporated into the knowledge object, inconsistency in the way in which the objects were constructed, and reduced the quality of their task product. Team C’s use of Issues showed a conversation can continue over time and relate to multiple versions of a knowledge object, meaning less effort by all group members is required to find useful information, and their own knowledge object trajectory is more accessible. Section 6.3.6 sets out recommendations for design to scaffold more consistent and effective use of the affordances across cohorts.

6.3.5. Bad tidying

In traditional group work, we tend to see the “approved” versions without much detail on the production process that occurs just before that point. While not generally addressed in knowledge building research, this study demonstrates that GitHub can make visible some processes of knowledge object modification that is usually forfeited through the mechanisms of production. These processes relate to minor text formatting and edits done by individuals without specific direction from the group. This is characterised here as “tidying”, because the comments accompanying the work indicate an intention in that direction, although the comments do not always adequately or accurately describe the changes that have been made.

In Team B, for example, there are several instances where individuals make changes to the shared knowledge object outside the approval process, and contrary to the team’s prior decisions. In one case, this involved modifying a model from feedback being provided to the learner from a data base developed by machine learning to being provided by a learning design; in the other cases it involved changes to terminology which had been negotiated by other teams members and used across multiple knowledge objects. While the environment offers multiple ways for these changes to be elaborated in a way which is meaningful to other team members, in each case the commit comments did not reflect the nature or scope of the changes, instead using ambiguous descriptions: “Typos, consistency and standardisation”, “fixed up some of the interactions” and “updating the README”. This is characterised in this study as ‘bad tidying’.

There was also ‘good tidying’. In Team A, for example, A1 actively engages in tidying activities over every week of the project, removing incorrect or outdated information, ensuring the documents are well-structured, and renaming the meeting notes in a consistent format, without discussion and a formal approval process, but not changing concepts or substantive content. In Team C, C4 and C3 ensure each page is well-formatted in Markdown and that diagrams display properly inline in the final weeks of the project, acting consistently with their structured approval process that allowed direct merging for ‘cosmetic changes’. However, C5, who, in a similar way to two team members from Team B, engaged only sporadically and superficially (in the sense their contributions were not epistemic or productive) and late in the process, went outside this workflow to make substantive changes that contradicted the decisions made by the rest of the team.

'Bad tidying' actions are unproductive for the quality of the knowledge object, and they also speak to the concerns expressed by students around group work, particularly in terms of equitable contributions and grading. While Team B had an agreed workflow process, these participants did not follow it and did not engage with previous team conversations in GitHub Issues where these matters had been discussed and determined. It might be reassuring for both students and instructors that GitHub data can reveal these actions which have the potential to create conflict and which impact other's contributions. Of course, another way to view this from a sociocultural viewpoint is that it is necessary for some team members to be awarded lower grades in relation to their knowledge object in order to facilitate their own and others' learning in other domains, as they may all have also built new knowledge that is not demonstrable through the assessment task, or yet discernible by the learners themselves.

6.3.6. Design recommendations

As an exploratory study, the results from this research can help guide design of learning environments which use professional knowledge environments as a collaborative platform. The findings show that GitHub can be used effectively for pedagogical designs based on knowledge building and trialogical learning, and more broadly is consistent with the underpinning theoretical framework based in sociocultural and constructivist conceptions of learning through authentic practical activity with others involving both social and cognitive mechanisms and leading to new understanding. However, the results show that there are opportunities to modify the task and environment conditions to further support the activity associated with increased productive interactions, knowledge object advancement, and the manifestation of agency as show by the findings around full participation (Section 6.1.1), a balance of epistemic and regulative activity (Section 6.1.2), and meaningful feedback processes (Section 6.1.2).

6.3.6.1. Full participation

It is not possible to eliminate the variability in group work which comes from the set of individuals which comprise the group and allow the creation of new knowledge, and, if our aim is to prepare learners for ad hoc collaboration in virtualised teams, the design strategy should enable regulation of participation and contributions by and within the group. In this study, higher levels of relational presence were associated with levels of participation, and where full participation did not occur it was mentioned indirectly by team members but not addressed directly. This indicates that affordances for shared monitoring of and communication about participation and contributions would support more participation.

The GitHub 'Insights' function reports on the number of commits performed in the repo for every contributor, and the number of characters which have been added and deleted. Increasing interest in business information metrics has led to the development of a range of GitHub 'dashboard' products that draw information directly from the repo, for example, GitStats (Hokkanen, 2015), Screenful (Screenful Oy, 2022) and Sumo Logic (Sumo Logic, 2022), however most also focus on volume of code changes. In group work settings, a word count of contributions is frequently used as a participation measure, but is problematic in that it does not measure the nature or quality of contributions (Strauß & Rummel, 2021). This study found Issues, Pull Requests and comments are a more meaningful indicator of engagement.

Modifying the learning design to set an expectation of a baseline frequency of interaction tied to the weekly incremental tasks is likely to increase both the sense of community (Zhang et al., 2009) and student familiarity with the system interface and features. Providing specific workflow guidelines and scaffolding around using Pull Requests with the review function will ensure that the frequency and nature of contributions are visible to all participants, and alert individuals that their input has been sought, supporting object-orientation (Paavola & Hakkarainen, 2005), goal-directed group awareness and socially shared regulation (Strauß & Rummel, 2021). Retaining the current task to reflect as a group and refine collaborative processes will provide flexibility for teams to appropriate social and environmental affordances (Hadwin et al., 2018) in their improvement of group processes (Paavola & Hakkarainen, 2005, 2014), balancing guidance and constraint (Wise & Schwarz, 2017) to support mutual regulation. This approach does not preclude more sophisticated technical solutions, for example, an argumentation dashboard (Han et al., 2021), social (Buder et al., 2021) or group awareness tool (Bodemer et al., 2018), or simple Excel spreadsheet, as the data is still available through the API and command-line access. By centralising the relevant information in the location most accessible to the groups themselves, monitoring can occur leading to the development of metacognition and consequent individual and group adaptation.

6.3.6.2. Balance of epistemic and regulative activity

Intentional learning in both professional and academic settings requires a combination of epistemic and regulative activity, sustained over time. This study found that a balance of epistemic and regulative activity within the group was associated with more productive interactions and knowledge object advancement, and that some groups engaged in less epistemic activity than others. This indicates that support for generating epistemic contributions will be useful in enabling our learners to create new knowledge.

Increased mutual participation and interaction through task and environment redesign can lead to activity across both these dimensions, and regulation can support the development of metacognition (Hadwin et al., 2018). Shifting the focus of group work from tasks to ideas is a key foundation of knowledge building pedagogy (Chan, 2013), but professional knowledge environments focus on productional rather than epistemic processes (Scardamalia, 2002). While the GitHub platform does not have the specific features found in designed knowledge building environments such as Knowledge Forum®, it does have affordances which can be appropriated for this purpose.

Modifying the task to specify a balance of epistemic and regulative activity could be supplemented by scaffolding for the use of GitHub labels (GitHub.com, 2020) indicating the classification of individual contributions across the epistemic, regulative, and other dimensions. These would be visible on each comment on each page for easy recognition by the team members, facilitating awareness of the nature and frequency of contributions as discussed in Section 6.3.6.1, and enabling all team members to monitor the collective epistemic as well as regulative progress, a necessary aspect of self-, co-, and socially shared regulation (Hadwin et al., 2018; Isohätälä et al., 2021). Each participant's encoding of their own contribution involves epistemic complexity, and requires cognitive effort to process, leading to greater understanding (Zhang et al., 2009). This approach would facilitate planning and reflection, collective visualisation, externalise and increase awareness of their own and each other's learning process (Hadwin et al., 2018; Järvelä et al., 2021), provoking metacognition and more efficient collaboration (Hurme et al., 2009; Järvelä et al., 2021). This data would also be exposed to the API and could be included in more technically advanced reporting formats.

6.3.6.3. Meaningful feedback processes

The fundamental basis for the sociocultural theory of learning and constructivism is that we learn by observing the ways in which things, including people, are different from each other. New knowledge creation requires eliciting, materialising and integrating multiple perspectives. In this study, negotiated and consistently enacted group feedback processes were associated with more iterative versions of knowledge objects incorporating more team members' suggestions. This indicates that affordances for structured feedback and shared decisions about how it will be applied would support the uptake of more ideas from more participants.

Learner-centred evaluation of ideas moving cognitive responsibility from teacher to learner is a key knowledge building principle (Scardamalia, 2002; Zhang et al., 2009), and constructive use of peer feedback is associated with the development of shared epistemic agency (Damşa & Ludvigsen, 2016). An important affordance of technology-enabled knowledge building environments is a system for peer review (Jeong & Hmelo-Silver, 2016). However, learners can struggle to use feedback effectively, and scaffolding, for example, with templates, can improve its quality and lead to better learning (Kollar et al., 2018). This study found that when learners were required to conduct a design critique initiated by the instructor, two of the three teams developed a scaffold for conducting the critique and the third team had developed a system using Issues which they applied across all feedback. However, those first two teams did not develop either a scaffold or a system for within-team feedback.

While a feature allowing a template to be applied to GitHub Pull Request Reviews is still not on the official development roadmap (GitHub.com, 2022), it has been regularly requested for the last four years, indicating the potential for its inclusion in the platform. Modifying the learning design to include scaffolding for co-construction of a feedback template and instantiating it as an asset in the repo which can be copied and pasted into the review template is a workaround which would be effective in the interim. The Pull Request review function can also capture the specific line number within the document which is the subject of feedback if desired, and whether each reviewer approves, does not approve, or approves the modification with suggested changes (GitHub.com, 2021a) providing a transparent view of which, and whose, ideas have been incorporated into the knowledge object, facilitating an equal and constructive exchange of ideas (Isohätälä et al., 2021) and the democratisation of knowledge (Scardamalia, 2002). By facilitating specific focus on team members' input, it is likely that team members will be motivated to participate meaningfully in the feedback process and engage in individual and collective self-evaluation leading to more knowledge advancement.

6.3.6.4. Relational presence

The results of this study indicate that there is scope for modifying the designed task and environment to support strategies that will increase productive actions and knowledge object advancement. Creating awareness of group activities, distributing the epistemic and regulative load, and scaffolding the development of others' ideas are all associated with the development of collective cognitive responsibility, our goal for our graduates, and a concept closely linked with epistemic agency. However, another factor was also identified in the differences between the way groups approached the collaboration which should not be overlooked.

It has been argued that because it tends to be technocentric in its development and implementation, the use of educational technology may have a negative impact on both social interactions and the learning process (Isohätälä et al., 2021). Online environments can make it difficult to feel connected with others, interpret social cues, and make inferences about others' emotions (Isohätälä et al., 2021). Socioemotional support, when combined with regulation, increase positive social interactions, which, when also combined with regulation, improve focus on the task and increase participation (Isohätälä et al., 2020). This support can include encouragement, complimenting, expressing appreciation and sympathy, apologising, and humour (Isohätälä et al., 2020).

While not the focus of this research, the variation in interactional tone between groups was notable, with groups whose communications had higher levels of what for analytical purposes here has been labelled 'relational presence' also having higher levels of interaction generally, productive interactions, knowledge object advancement, individual and shared epistemic agency. While neither research on socially-shared regulation for learning nor on shared epistemic agency have previously explored the relational features of asynchronous communication that also have epistemic and regulative content, this association indicates an important relationship which relates to the central concern of Isohätälä et al. (2021) around social sensitivity. Modifying the designed environment to include scaffolding for communicative interactions at high, medium and low levels of relational presence, and making explicit connections between socioemotionally-aware interactions and the experience and outcomes of higher education group work, could improve both those experiences and those outcomes.

6.3.7. Summary

While teams sometimes found using GitHub for knowledge building challenging, deliberate design of both the task and environment has the potential to facilitate full participation, a balance of epistemic and regulative activities, meaningful feedback processes and a high level of relational presence. As the principles of knowledge creation emphasise self-organised and socially emergent processes (Paavola & Hakkarainen, 2021; Scardamalia & Bereiter, 2014b), there is some risk that over-specification of the learning environment may reduce the socially emergent negotiated aspect of collaboration (Reimann & Kay, 2010). However, this is balanced by reduction in cognitive load resulting from using fewer affordances in a more consistent way, and the retention of task and environment features which allow groups to design, reflect on, and continually improve their collaborative processes and knowledge objects.

6.4. GitHub as a tool for research on collaboration

This study explored GitHub as a platform through which group work research could be conducted, and the results indicate that it can provide insights into the collaborative process which might not be observable by the instructor, reported by the teams themselves or visible in traditional technology-mediated environments. The study also reinforced the complexity of conducting a systematic analysis of interaction and object content trajectories described by Baker et al. (2021); Damşa (2014); Damşa and Ludvigsen (2016). While in theory an online environment offers straightforward access to learner data, the different ways in which the teams used GitHub, and particular GitHub interface limitations, meant accessing, organising and analysing the data was challenging. However, with attention to the design considerations set out in Section 6.36, the data from GitHub has the potential to support important directions in CSCL research.

In this study, one research consideration were that event and interaction data were difficult to output in a format which is useful for machine analysis. The GUI pages are not well-structured for readability, and the data output for event type must be accessed separately so a constraint for data access, particularly for exploratory studies, is that the researcher needs to know which event types have been used. Without this knowledge, from the 923 rows of data extracted across Team B's repo in the initial access, none contained the comment on Issue #9 which could be viewed in the GUI by manually clicking a button within the document Pull Request.

Review comments can only be viewed in the GUI one file at a time and also don't count in the summary of "Conversations", for example, Issue #80 shows (4) conversations in the bubble, but with the review comment, there are actually five. Another was that without a designed and consistent approach to workflow, it was not always possible to connect an interaction with a change to a knowledge object, and this identification had to be done manually in order to identify 'productive' interactions and thus shared epistemic agency. There is a small administrative load in setting up the group repos prior to the project and some technical courage involved in learning how to access the data at the back end.

When data can be collected by command-line scripting or the REST API (GitHub.com, 2021e), it is well-formed, with each communication bounded and a single action returned per row, and can easily be converted to plain or comma-separated text. There are several contemporary streams of CSCL research which already use interaction data in similar structures to this to support human or machine analysis. While a full consideration of these approaches is beyond the scope of this thesis, three are mentioned briefly below.

6.4.1. Social and cognitive awareness

There has been sustained interest in supporting the social dimension of technology-mediated interaction, with researchers, instructors, and the learners themselves all different audiences for data describing 'who', 'what' and 'where' information (Buder et al., 2021). Although the basis for that research aimed to emulate information that would be available in face-to-face experiences (Buder et al., 2021), this study shows that data such as unsanctioned changes to the knowledge object by individuals which would not be visible in those experiences is available in GitHub and can supplement other information about who is contributing what where to the shared project.

Following the design recommendations in Section 6.3.6 will improve the quality of data available to explore how awareness of others' activities influences collaborative learning outcomes in two ways. A standardised workflow limits the number of event types that need to be retrieved and associates each interaction with a specific knowledge object. Together with student labelling of their contributions across the epistemic and regulative dimensions, and the system capture of feedback and its uptake, these strategies will substantially reduce the complexity of data collection and coding, and the resourcing required to observe how learners use this additional information about the participation of others in their individual and shared regulation.

Additional support for the investigation of social factors in group work is available through review of the relational level of communications. With GitHub plugins that can conduct sentiment analysis on Issues, Pull Requests and review comments already available (trstringer, 2022), identifying associations between the interconnected and inextricable threads of social, relational, epistemic, regulative and productional activity awareness will be more viable for both manual and automated analysis.

6.4.2. Network analysis

Network analysis has been substantially adopted in CSCL to analyse structural patterns in discourse and knowledge evolution (Oshima & Hoppe, 2021), and data from interaction logs are the basis for the burgeoning field of learning analytics (Oshima & Hoppe, 2021). While traditional social network analysis could be limited to participatory patterns, several studies have already combined text and network analysis of data from the Knowledge Forum® environment (Lee & Tan, 2017b; Oshima et al., 2012) to explore how some ideas in a discourse are eliminated by the group, and others are pursued and improved (Lee & Tan, 2017b). More recent Knowledge Forum® studies illustrate the potential for knowledge building interaction data to inform the design of learning settings facilitating engagement and knowledge advancement (Lin et al., 2020; Yang et al., 2022; Zhu et al., 2021).Epistemic network analysis uses structural modelling to identify patterns in the discourse of successful learners and compare the network graph of an optimal outcome measure with the graph of a group of leaners working toward that expertise (Shaffer, 2017). Both these approaches understand participant vocabulary to be indicative of the extent to which the learners can explain the relevance and potential of their ideas to others (Lee & Tan, 2017a).

The trajectory data available from GitHub contains the necessary fields to construct a network analysis of participation, engagement and discourse over time, linked to observable changes in the shared knowledge objects. The additional data available if the design recommendations in Section 6.3.6 are implemented will complement existing approaches by adding metacognitive monitoring data in the labelling of contributions.

By using machine analysis to interpret GitHub data, researchers can investigate the multiple types of networks across these diverse variables at scale, allowing comparison across multiple datasets both live and retrospectively. These approaches can also be combined with sentiment or other natural language analysis to understand how the tone of communication is related to both social and epistemic network development.

6.4.3. Process analysis

There is significant interest in the intersection of socio-emotional-motivational variables in research on collaborative learning, with both participation in social interaction and the emotional tone of communication associated with the regulation of learning (Isohätälä et al., 2020). However, investigating these factors is time-consuming and labour-intensive (Järvelä et al., 2021). While multimodal data is considered preferable for understanding how these operate in collaborative learning, this study shows that differences in the relational level of interactions can be observed and associated with epistemic and regulative activity in the GitHub data.

Constructing a trajectory view of collaboration is recognised as a significant current methodological challenge in CSCL, (Baker et al., 2021; Damşa, 2014; Damşa & Ludvigsen, 2016; Paavola & Hakkarainen, 2021). The design recommendations in Section 6.3.6 can simplify this identification and analysis and provide data in a consistent and machine-interpretable form.

The combination of time-sequenced data about the frequency and nature of knowledge, process, and social activity available from GitHub could increase the scope of research into socially shared regulation for learning by providing a trajectory of activity in an asynchronous online context, and over a period of time, not usually encompassed by studies in this area, and to contribute to further studies in shared epistemic agency. It can be combined with other kinds of data collection, for example, physiological data, to triangulate the results and reveal new understanding of the relationship between those processes and asynchronous online collaboration activity.

6.4.4. Summary

GitHub data can provide useful input to research on knowledge building and, more generally, collaboration for learning. It allows the construction and testing of hypotheses, for example, network maps and trajectory patterns, as well as traditional discourse and interaction analyses.

The data output supports a blend of quantitative and qualitative approaches that can be further enhanced by smart technology such as sentiment analysis or Natural Language Processing. The data structure supports a range of methodologies including but not limited to those suggested in Sections 6.4.1, 6.4.2, and 6.4.3 above. The platform supports live interrogation through the REST API and the command line, and multiple visual representations through existing and potential graphical displays.

The design recommendations in Section 6.3.6 can improve data quality, interoperability, and reduce collection and processing time. As well as a metacognitive strategy and coding affordance, learner labelling of their contributions with the appropriate category also reduces the requirement for triangulation, as intentionality can be inferred with more reliability. A specified workflow combined with machine analysis could be further extended to conduct a direct machine comparison between different knowledge objects.

Together, these allow analysis to be done at a scale that is difficult to achieve in traditional approaches to collaboration research. This combination of digital infrastructures, environments and communicative situations have been termed *platformisation* (Baker et al., 2021). Baker suggests this is a fruitful ground for computational approaches to analysis, and while GitHub's downloadable text output will facilitate this for researchers interested in data interoperability, the GUI view of trajectories allows easy instructor access to team interaction activity, different coding and analytical methods such as simple qualitative analysis, or a blend of computational and qualitative approaches.

This combination of design and technical affordances shows that GitHub is a promising ground for future research on project-based higher education group work.

7. Conclusions

The previous chapter presented a discussion of the research findings, and the resulting recommendations for pedagogical and technical design strategies to support participation, epistemic activity, and meaningful feedback. This chapter provides an answer to the research questions, acknowledges the limitations of the research, and considers the implications of the findings. Section 7.1 presents the conclusions of the study. Section 7.2 summarises the resulting considerations for learning design and research. Section 7.3 discusses some limitations to the study and Section 7.4 closes the body of this thesis with a summary of the contributions this work has made to the field of CSCL.

7.1. Answering the research questions

The aim of the study was to contribute to research on designing for effective technology-enabled collaborative learning for project-based group work in higher education by exploring the use of a professional knowledge environment. The study investigated this through an analysis of the interaction data that resulted from three university student groups using the GitHub platform for a collaborative modelling task. The research questions were:

1. What kind of agency emerges when university students work on project-based tasks using professional knowledge environments?
    i. at individual level
    ii. at group level
2. How can the data generated by group work in professional knowledge environments be used for research on knowledge co-creation?

This study found that individual, joint, and shared epistemic agency emerged among the student groups in different ways and at different levels and could be observed in the GitHub data (Section 6.1) through the classification of individual actions (Sections 5.2-5.5) combined with a trajectory analysis of joint interactions and changes to the shared knowledge objects (Section 5.10-5.14). There were differences within groups in individual participation (Section 6.1.1), and differences in the general approach each group took to the collaboration (Section 5.9). The findings demonstrate that a group's general approach to collaboration can be located in GitHub asynchronous interaction data with a reasonable level of reliability (Sections 5.7-5.9).

These differences in approach were associated with differences in the levels of productive interaction leading to improvements in their knowledge objects (Section 6.1.2). The analysis indicated these differences were in three main areas which could be addressed by task and environment design modification (Section 6.3.6). However, while full participation, a balance of regulative activity, and meaningful feedback processes can be designed for, the results also showed that students do not always use the learning and environment design the way it is intended (Section 6.3.5).

More broadly, the findings indicate that the GitHub platform can meaningfully support knowledge building pedagogies (Section 6.3.1), group modelling work (Section 6.3.2), and object-oriented collaboration (Section 6.3.3). An unexpected factor in the study was the emergence of a relational layer in interpersonal communications (Section 6.2) which was associated with more productive interactions and knowledge advancement.

This study demonstrated that the data generated through GitHub interactions (whether asynchronous or synchronous) can be successfully used to conduct thematic (Sections 5.2-5.6) and trajectory (Sections 5.10-5.14) analyses of group work processes. Through this exploration, it was possible to identify the necessary data components for these methods (Section 4.6) and procedures for their collection (Section 4.5) and analysis (Sections 4.7-4.10). The pedagogical design recommendations developed in response to the first research question will also improve future data collection, coding and analysis processes.

The findings show that the data structure, format and accessibility has the potential to be used by multiple analytical voices (Section 6.4), immediately or retrospectively, through simple or complex technical manipulation. The platform is expanding to encompass novel visualisations and data integration with other systems and services (Section 6.4.4), which could decrease resistance to institutional implementation and increase the scale at which research could be conducted and datasets and results compared.

7.2. Considerations for further research

Asynchronous collaboration environments such as GitHub are increasing in use worldwide, and it is likely that systems of this nature will form part of the future workplace because of their capacity to support distributed global teams across multiple projects, organisations, and time zones. For students doing group work at university, it is an important opportunity to familiarise themselves with this kind of environment while supported to manage the technical requirements and the process of co-constructing knowledge objects within it. This study has identified some of the challenges for students participating in project-based group modelling work in GitHub, and researchers analysing the resulting data. Recommendations for task and environment design modifications to improve participation, increase epistemic activity, and support constructive feedback processes for learners, and data quality for thematic and trajectory analysis for researchers, are considered at Section 6.3.6, and opportunities for using GitHub data for exploration of social and cognitive awareness, network analysis and process analysis are outlined in Section 6.4. In addition to these research directions, other avenues of interesting inquiry might be considered.

While this study has touched on the relationship between individual and collective agency, there is scope for GitHub data to contribute further in the investigation of how the two levels interact. This study observed a relationship between individual actions and the approach to collaboration by the group. However, as an exploratory study this can not be generalised and further support for this finding would increase its validity and may provide additional context as to the conditions under which this occurs. This need for individual agency to create the conditions for the agency of others to emerge remains a design challenge for both education and the workplace.

Although studies on agency have not significantly addressed the relational tone of communication, this study indicates it impacts on the collaborative process and the learning outcomes, with further research required on its association with both epistemic and regulative activity by individuals and groups. Where research has been conducted around socio-emotional interactions, it tends to be small scale, focused on micro-interactions that are classified as <u>either</u> socio-emotional <u>or</u> something else. Considering socio-emotional engagement as a metacommunicative layer which can co-exist and influence the interpretation of another communicative layer might provide insights into the socially sensitive use of technology-enabled learning environments.

The results of this research have also shown that student concerns about collaborative work in relation to equitable contributions and grading are valid. Consideration should be given to conducting research on collaborative assessment in professional knowledge environments to access a transparent view of all student actions in relation to shared knowledge objects, to develop designs which balance the multiple personal, social, and motivational frames that different learners bring to group tasks.

Finally, this study provides evidence that professional knowledge environments such as GitHub support pedagogical designs based on knowledge building and trialogical learning. There is a substantial body of research in relation to knowledge building conducted in schools, but less on project-based group work in higher education. GitHub provides a platform from which to develop a global community around its use in university collaboration and engage in this research at scale.

7.3. Limitations

There are some limitations to this study in relation to its completeness, generalisability and validity.

While the results of this research are promising in their potential to reveal important aspects of interaction at scale, because asynch conversations are only 'half' the conversation, we can't say that this is the full picture of the collaboration. The data collection may not have captured backchannel communication, although there were no indications that it was used. While the additional data analysis can point us to whether the general view on the nature of the collaboration, and specifically the research questions in relation to indicators of epistemic agency and differences between groups, has validity, the analysis is still in a way incomplete without synchronous data. However, to some extent all analyses of collaborative work are incomplete because our view of learners can only ever be partial, and we deal with that through acknowledging the limitations and looking for the most effective and useful partial data. This study's methodological contribution allows that partial data to be integrated with other data sources to create a more developed picture.

The results of this study are not readily generalisable, not only because of the small number of participants and non-probability sampling, but also because of the unique characteristics of learner and workplace groups that result from contextual circumstances that can not be predicted or controlled. A university administrative deadline change led to students withdrawing from the unit after the project had begun which may have impacted the findings particularly for Team A, and differing use of the roles suggested in the scaffolding may also have influenced the collaborative process. As computer-support collaborative learning is situated predominantly within a western paradigm of sociocultural theory, this study's findings may not be generalisable to cultures that take a collectivist approach and where the teacher is the ultimate source of authority.

As a novice researcher without a formal external validation mechanism and working with asynchronous data, there is a question as to the degree of validity in relation to my conjectures about how each group worked together, and how individuals and groups interpreted the relational level of communications. The secondary analysis was included in the method to establish validity for the conjectures, but that was still asynchronous data and not able to be confirmed by student participants. This is a result of the COVID-19 pandemic impacting a planned research study, providing an opportunity to explore the use of asynchronous data.

The way in which the relational layer of communication was conceptualised is based on a framework which does not specifically address contemporary technologies, however I was not able to locate more recent work which could be meaningfully applied to the message type as a metacommunicative layer. The classification examples are limited to those found in the data for these three groups and will not reflect the full range of relational elements possible across asynchronous platforms.

There were instances where the coding of actions and interactions was not clear, for example, if the appropriation of the GitHub features in some cases was also an epistemic act. The question also arises as to what extent we can classify changes to the knowledge object in epistemic or regulative dimensions, and whether this separation is meaningful in a sociotechnical environment that affords individualised user appropriation of features and tools. Actions such as identifying how to make a model diagram display properly on the page have an epistemic flavour, even if they are to some extent simply technical. While we have followed the original classification method here to closely align with previous studies, and to distinguish the kinds of contributions that are not necessarily visible in the traditional kind of knowledge object collaboration within that framework, in future research this distinction should be further considered.

From a personal perspective, I found it very difficult to be impartial toward those participants who made their team’s work worse, or who consistently failed to read the thoughts and decisions that had been discussed in meetings and on GitHub before taking action or asking questions. This is grounded in my poor experiences of group work, which in turn, is part of the reason I am interested in collaboration from a research point of view. To address this I developed the data-driven coding procedure for both interactional and relational communications, making classification a more technical (and potentially automatable) process.

7.4. Contribution to the field

This thesis presents the findings of a research study into the use of GitHub as a collaborative learning platform for university students engaged in a project-based group modelling task. It found that GitHub supports knowledge building pedagogies and research into computer-supported collaborative learning. It makes a scholarly contribution to the field through exploring a novel technology with an established research method, providing support for existing research and extending its application to platforms that support the collaborative development of complex model knowledge objects. It makes a methodological contribution in its investigation of data collection and analysis processes that reduce the resourcing load for research on collaboration using GitHub. It makes a design contribution in its recommendations for pedagogical strategies to improve the learning experience and outcomes for group work participants, and an innovation contribution in its suggestions as to other research methodologies which could profitably use the interaction data. Most importantly, it found that group work does not have to suck.

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Appendix A

Human Ethics Protocol 2019/049

03/06/2022, 18:05 IRMA

THE UNIVERSITY OF SYDNEY **IRMA Human Ethics Protocol**

| My preferences | Researcher Profile | Desktop | Logout
| Record now unlocked, exit the record to acquire edit rights | Miss E A Black

Home ▸ HE Protocol ▸

Grants | Snapshot
Documents | Authorities
Main Details | Investigators | Departments | Questionnaire | Coversheets

Amend

This tab is read-only

Cancel | Print Form

Created by:	1150594
Record number:	9171
Protocol number:	2019/049
Date entered*:	19/02/2019
Program type:	Undergraduate
Requested start date:*	26/03/2019
Requested end date:*	26/03/2023
Protocol title*:	Learning to learn with others through collaborative modelling: CSCL designs facilitating successful collaboration and knowledge advancement.
Protocol type:	Low Risk Application
Clinical trial:	To be confirmed
Internal ref:	
TRIM id:	
Clearance status:	In-progress

| Disclaimer | Privacy |

Please direct all enquiries to: Research Portfolio Systems
University of Sydney

Appendix B

Participant Information Statement

THE UNIVERSITY OF SYDNEY

Discipline of Education
School of Education & Social Work
Faculty of Arts & Social Sciences

ABN 15 211 513 464

PROFESSOR PETER REIMANN
Professor of Education, Centre for Research on Learning & Innovation

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Education A35
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Learning to learn with others through collaborative modelling

PARTICIPANT INFORMATION STATEMENT

(1) What is this study about?

You are invited to take part in a research study about the effect of on how learners' ideas move through individuals and groups in collaborative projects, and how students and groups use design tools to collaborate on complex system models.

You have been invited to participate in this study because you are attending a workshop about using the Repertory Grid Technique in teaching and research. This Participant Information Statement tells you about the research study. Knowing what is involved will help you decide if you want to take part in the research. Please read this sheet carefully and ask questions about anything that you don't understand or want to know more about.

Participation in this research study is voluntary.

By giving your consent to take part in this study you are telling us that you:

- ✓ Understand what you have read.
- ✓ Agree to take part in the research study as outlined below.
- ✓ Agree to the use of your personal information as described.

You will be given a copy of this Participant Information Statement to keep.

(2) Who is running the study?

Elizabeth Black is conducting this study as the basis for the degree of Doctor of Philosophy at the University of Sydney. This will take place under the supervision of Professor Peter Reimann, Professor of Education, Centre for Research on Learning & Innovation, the University of Sydney.

(3) What will the study involve for me?

Before and after you complete the workshop on Repertory Grid Technique, you will be asked to complete an online survey. The survey will ask you about your understanding of the technique.

Once all the survey data is available to the researcher, you may also participate in a brief (30 minute) individual interview. The purpose of this is to provide insights into how you (in contrast to the researcher) experienced learning about the technique, and to check whether the researcher interpretation of your responses is aligned or not with your intention..

(4) How much of my time will the study take?
The surveys will take around ten minutes each.

(5) Who can take part in the study?
At the moment, this study is limited to specific cohorts for which Human Ethics approval has been received.

(6) Do I have to be in the study? Can I withdraw from the study once I've started?
Being in this study is completely voluntary and you do not have to take part. Your decision whether to participate will not affect your current or future relationship with the researchers or anyone else at the University of Sydney. No part of your activities in this workshop will be assessed, and the researcher will not access the data until the workshop has been completed.

Submitting your completed consent form is an indication of your consent to participate in the study. If you decide to take part in the study and then change your mind later, you are free to withdraw at any time up to the point that we have published the results. You can do this by contacting the researcher through the Canvas site while it is available, and afterward at eablack@uni.sydney.edu.au. If you use a pseudonym, your responses cannot be withdrawn because they are anonymous and therefore we will not be able to tell which one is yours.

If you decide to withdraw from the study, we will not collect any more information from you, and will remove the responses we have recorded up to that time.

(7) Are there any risks or costs associated with being in the study?
Aside from giving up your time, we do not expect that there will be any risks or costs associated with taking part in this study.

(8) Are there any benefits associated with being in the study?
We cannot guarantee that you will receive any direct benefits from being in the study, but intend the design to be helpful for both the unit learning outcomes and the process of collaboration.

(9) What will happen to information about me that is collected during the study?
Information will be collected about collaborative and modelling interactions and knowledge objects and while individual contributions may be identifiable, personal information will be anonymised. Interaction data, which may include audio, visual, textual or other representational forms which might be the subject of analysis will be uploaded to the university's REDCap research data system and retained in line with a formal Research Data Management Plan. Your information will be stored securely, and your identity and information will be kept strictly confidential, except as required by law.

Results from this research project will form the substance of a doctoral thesis and be presented at the University of Sydney Research Fest among other colloquia and publications connected with the Learning Sciences and Computer-Supported Collaborative Learning. The aim is to connect with other research in similar areas through submissions to relevant Learning Sciences events and deepen and broaden the research base. If you have any concerns or questions about how your responses will be used or the Research Data Management Plan please contact the researcher through the Canvas site. Study findings may be published, but you will not be individually identifiable in these publications.

The information from this project may be provided to other researchers so that they can use it in their projects. Before that happens, all the personally identifying information will be removed, so that the people we give it to won't know whose information it is. They won't know that you participated in the project and they won't be able to link you to any of the information you provided.

The information collected for this study may be retained and may be used in future projects. By providing your consent you are allowing your information to be used in future projects, unless you withdraw your consent later. It is not known at this stage what these other projects may involve. Ethical approval will always be required before using the information in these future projects.

These measures comply with the Australian National Data Service guidelines for publishing and sharing sensitive data). In line with University of Sydney policy, the data will be kept for five years after the project, when destruction of data is required it will be carried out in accordance with the Research Data Management Policy and Research Data Management Procedures.

(10) Can I tell other people about the study?
Yes, you are welcome to tell other people about the study.

(11) What if I would like further information about the study?
When you have read this information, Peter and Elizabeth will be available to discuss it with you further and answer any questions you may have. If you would like to know more at any stage during the study, please feel free to contact Elizabeth at eablack@uni.sydney.edu.au.

(12) Will I be told the results of the study?
You have a right (and are encouraged) to receive feedback about the overall results of this study. You can tell us that you wish to receive feedback by ticking "I'd like to keep informed about this study" on your Participant Consent Form. Initial feedback will be in the form of a single page summary of results, and you will also be able to opt-in to receiving further research related to this study if you choose to. This feedback will be provided after the analysis, which might take 6-12 months after your participation. If you would like to know when this will be available, please feel free to contact Elizabeth at eablack@uni.sydney.edu.au for updates.

(13) What if I have a complaint or any concerns?
Research involving humans in Australia is reviewed by an independent group of people called a Human Research Ethics Committee (HREC). The ethical aspects of this study have been approved by the HREC of the University of Sydney [2019/049]. As part of this process, we have agreed to carry out the study according to the *National Statement on Ethical Conduct in Human Research (2007)*. This statement has been developed to protect people who agree to take part in research studies.

If you are concerned about the way this study is being conducted or you wish to make a complaint to someone independent from the study, please contact the university using the details outlined below. Please quote the study title and protocol number above.

The Manager, Ethics Administration, University of Sydney:

- **Telephone:** +61 2 8627 8176
- **Email:** human.ethics@sydney.edu.au
- **Fax:** +61 2 8627 8177 (Facsimile)

This information sheet is for you to keep.

Appendix C

Participant Consent Form

THE UNIVERSITY OF SYDNEY

Discipline of Education
School of Education & Social Work
Faculty of Arts & Social Sciences

ABN 15 211 513 464

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Learning to learn with others through collaborative modelling

PARTICIPANT CONSENT FORM

I, ...

[please print your name], agree to take part in this research study.

In giving my consent I state that:

- ✓ I understand the purpose of the study, what I will be asked to do, and any risks/benefits involved.
- ✓ I have read the Participant Information Statement and have been able to discuss my involvement in the study with the researchers if I wished to do so.
- ✓ The researchers have answered any questions that I had about the study and I am happy with the answers.
- ✓ I understand that being in this study is completely voluntary and I do not have to take part. My decision whether to be in the study will not affect my relationship with the researchers or anyone else at the University of Sydney now or in the future.
- ✓ I understand that I can withdraw from the study at any time up until the point that the results of the study have been published..
- ✓ I understand that personal information about me that is collected over the course of this project will be stored securely and will only be used for purposes that I have agreed to. I understand that information about me will only be told to others with my permission, except as required by law.
- ✓ I understand that the results of this study may be published, and that publications will not contain my name or any identifiable information about me.

I consent to:

Audio-recording	yes	no
Video-recording	yes	no
Photographs	yes	no
Being contacted about future studies	yes	no

Further communications about the study

I would like to review my interview transcripts [ ] YES [ ] NO

I would like to receive feedback about my personal results [ ] YES [ ] NO

I would like to receive feedback about the overall results of this study [ ] YES [ ] NO

If you answered YES to reviewing the transcripts and/or receiving feedback, please indicate your preferred form of feedback above and preferred delivery address below:

[ ] Post ____

[ ] Email ____

....

Signature

....

Please PRINT your name

....

Date

Appendix D

Research Data Management Plan

THE UNIVERSITY OF SYDNEY

Discipline of Education
School of Education & Social Work
Faculty of Arts & Social Sciences

ABN 15 211 513 464

Learning to learn with others through collaborative modelling

RESEARCH DATA MANAGEMENT PLAN

The University of Sydney offers a range of different tools to help manage research data, and there is an expectation that researchers use these platforms in order to comply with Research Data Management requirements.

DATA COLLECTION

The data collection does not contain personal information other than an identifying field for each student. Data Collection 1 will use the secure REDCap system. Data Collections 2 and 3 will use the secure WebGrid online service (http://webgrid.uvic.ca/), where responses will be sent to a unique cache in real time with single researcher login and password, then moved back to REDCap and the cache deleted. Students will not need to use their own name, simply a unique identifier that is consistent over the data collection phases in order to measure the change in those ratings.

The student interaction data, which may include audio, visual, textual material and assessment submissions which will be the subject of analysis will also be uploaded to REDCap and retained in line with this plan. Demographic data will not be collected in this study.

DOCUMENTATION AND METADATA

The research proposal, researcher details, and participant information will be linked from the REDCap project to allow oversight while retaining confidentiality. Project metadata will be constructed based on project keywords plus contextually relevant information, in structured, administrative and descriptive dimensions. At each iteration of the data collection process, the data will be downloaded from the collaborative environment and uploaded to the REDCap database, which will be duplicated to the Research Data Store for secure and redundant storage. Access and security will be managed by the researcher with fine control available through the University's Research Data Management platforms REDCap and the Research Data Store.

ETHICS AND LEGAL COMPLIANCE

It is unlikely that ethical issues will arise during the course of the study. The project is designed to be meaningfully embedded within the unit of study, linguistically and culturally agnostic and with data collection parameters that use only personally relevant responses. Students will all undertake the intervention as equals and are free to withdraw participation consent at any time. If participation consent is withdrawn, data related to that participant will be deleted and a log of the deletion maintained in the REDCap system. While it is unlikely that the data collected constitutes "personal information" as defined in the *Privacy Act 1988*, all information will be collected, stored, used and disclosed in accordance with relevant privacy laws, with only de-identified data used for publication and further research.

The project does not aim to invent Intellectual Property nor does it use proprietary materials, except where permitted by copyright and appropriately attributed.

STORAGE AND BACKUP

At this stage of the project, the REDCap data management environment appears most suitable for mostly numeric data which may over the course of the study also include personal information which needs robust protection, backup and disaster recovery. An overview of supported research data management platforms is at Figure 1. The environment is described as "ideal for collecting and managing participant data and administering online surveys, with features supporting longitudinal data collection, complex team workflows and exports to a range of statistical analysis programs". While integration of contextual information, notation and commentary is not a strength of this system, its web-based nature accommodates links to other suitable University locations for research description and dissemination.

Features for best-practice Research Data Management	eNotebook (LabArchives)	REDCap	Office365 (OneDrive)	Dropbox (Enterprise)	Code Repository (GitHub)	Cloudstor	RDS RCOS	Portable Devices
Sensitive data?	⚠️ 1	✅	⚠️ 1	⚠️ 1	⚠️ 1	⚠️ 1	⚠️ 1	⚠️ 1
Stored in Australia	✅	✅	✅	❌ 2	✅	✅	✅	⚠️
Accessible off campus	✅	✅	✅	✅	✅	✅	⚠️ 3	⚠️
External collaborator access	✅	✅	✅	✅	⚠️ 4	⚠️ 5	⚠️ 4	❌
Syncing with local copy	❌	❌	✅	✅	✅ 6	✅	⚠️ 7	-
Unlimited storage: staff (@sydney.edu.au)	✅	✅	3TB	✅	✅	100GB	✅	❌
Unlimited storage: students (@uni.sydney.edu.au)	✅	✅	1TB	15GB	✅	100GB	✅	❌
Individual file size limit	4GB *browser* Unlimited *RDS integration*	200MB	15GB	20GB *browser* Unlimited *client*	100MB *standard* 2GB *Git LFS*	2GB *browser* 2TB *FileSender*	Unlimited	Device storage
Ability to enter and manage contextual information, notation and commentary	✅	⚠️ 8	⚠️ 9	✅	✅	❌	❌	⚠️
Full audit trail (IP and research integrity)	✅	✅	✅	✅	✅	❌	❌	❌
All versioning kept for >min retention (5 years)	✅	✅	✅	❌ 10	✅	❌	❌	❌
Backup and disaster recovery	✅	✅	✅	⚠️ 10	✅	⚠️ 11	✅	❌

⚠️ 1-12 See footnotes on webpage (https://informatics.sydney.edu.au/rdm/platforms-comparison/)

Figure 1: Comparison of supported Research Data Management Platforms (from https://informatics.sydney.edu.au/rdm/platforms-comparison)

To ensure long-term storage maintains utility and privacy, the researcher will upload textual and numeric data in simple and non-proprietary file formats such as .TXT and .CSV, and ensure that copies are maintained both in REDCap and the Research Data Store. Audiovisual data will be converted to .MP3 or .MP4. It is intended that the pilot and subsequent datasets will comprise a growing store of evidence and continue to be added to over time. In line with University of Sydney policy, the data will be kept for five years after the project, when destruction of data is required it will be carried out in accordance with the Research Data Management Policy and Research Data Management Procedures.

DATA SHARING

Participants will be informed that their responses may be shared with other researchers in de-identified form, with the Australian National Data Service guidelines for publishing and sharing sensitive data).

Appendix E

Resources for the group project - LMS

Group formation and links to team Adobe Connect Room & GitHub repo

Analysing community sites

Texts (supplied as PDF)

Whitworth, B. (2009). The Social Requirements of Technical Systems. In B. Whitworth & A. de Moor (Eds.), Handbook of research on socio-technical design and social networking systems. Hershey, PA: Information Science Reference. (pp. 2-22)

Herrmann, T. (2009). Systems Design with the socio-technical walkthrough. In B. Whitworth & A. de Moor (Eds.), Handbook of research on socio-technical design and social networking systems. Hershey, PA: Information Science Reference. (pp. 336–351)

Kraut, R. E., & Resnick, P. (2012). Encouraging contribution to online communities. Building successful online communities: Evidence-based social design. (pp. 21-76)

Ren, Y., Kraut, R., Kiesler, S., & Resnick, P. (2012). Encouraging commitment in online communities. Building successful online communities: Evidence-based social design. (pp. 77-124)

Kiesler, S., Kraut, R., Resnick, P., & Kittur, A. (2012). Regulating behavior in online communities. Building successful online communities: Evidence-based social design. (pp. 125-178).

Kraut, R., Burke, M., Riedl, J., & Resnick, P. (2012). The challenges of dealing with newcomers. Building successful online communities: Evidence-based social design. (pp. 179-230)

Resnick, P., Konstan, J., Chen, Y., & Kraut, R. E. (2012). Starting new online communities. Building successful online communities: Evidence-based social design. (pp. 231-280)

Creating design patterns

While many resources around design patterns place them in a software development context, they are meta-models which can be applied to almost any situation where considerations of structure and sequence are important.

Beginner

- Watch this simple introduction to design patterns in educational contexts[1] from the International Academic Forum (IAFOR) on Vimeo.

[1] Links in this section may no longer be live or may require an institutional login.

- You can find examples of educational design patterns as well as resources and readings at the, and also at the Learning Design Grid.

Intermediate

- Log in to lynda.com, then go to Design Patterns, and watch the *Design Patterns* overview in Chapter 5: Interaction Design.

Advanced

- Also on lynda.com., while you won't have time to to the whole course on Universal Principles of Design, the chapter on *Flow* might be useful in understanding the balance between skill and difficulty necessary for deep engagement.

Creating design models

Beginner

- Both and have easy-to-copy model examples as well as servers you can test your code one to generate a real-time model.
- On , scroll down to see the different kinds of models you can create. Practice by copying the code on the left of the *State Diagram* (just above the *Test/Encoder* field). Paste it in to the left-hand *Test/Encoder* field and replace the word "another" with the word "steel". Click **Test/Encode**. You will see to the right an encoding of your input, and to the right of that your first model, hopefully with the word "steel" as the second item in *State 1* . Copy the code in your left-hand field, including the "steel" change.
- Go to , scroll down to the bottom where you can see *Example:* above a text input field. Paste your copied code and then enter/return. Does it work? Look at the example. What differences do you notice? Go back to the input field and modify your code until you can display the diagram without error.

Intermediate

- is a simple but powerful PlantUML test site, where you can select a model template from a drop-down list, then modify it in the editor to display a real-time graph. Think of these templates as design patterns ready to be adapted to your context.
- Sparx Systems' UML Tutorial has a simple overview of the different kinds of UML models and their use cases, but not the code that they are constructed from.
- A short, useful introduction to Use Case Models on youtube: UML Use Case Diagram Tutorial.
- And here for Activity diagrams: UML 2.0 Activity Diagrams.
- Load up and , then follow along with the activity on Vimeo Model activities in the design/teaching/learning process. This video describes how to combine activity diagram descriptions and Table feedback loop descriptions with text editing in a single document, written as plain text and markdown.

Advanced

- Download the for advanced editing including changing graph element colors and styles.
- IBM's module on Activity diagrams: What they are and how to use them has some advanced use case examples.

Collaborating in GitHub

While you can download and install GitHub on your device, or run it from a command line, you might find the easiest way to use it is the web GUI at https://github.sydney.edu.au/.

Beginner

- Log in to , register for and try out the course. Just use your university email address and password (not unikey) and accept the Terms & Conditions. This will take less than an hour and introduce you to the features we will use in our first (non-assessable) pair task.
- Test your new knowledge with https://guides.github.com/activities/hello-world/. Follow the instructions and complete the activity to create your own repo, start and manage a new branch, create and change a file, open and merge a pull request, and get GitHub kudos squares. Activities you do in your own repo will not affect the class repo or those of your colleagues.

Intermediate

- The first 5'30" of this GitHub Collaboration Tutorial introduces the different communication and workflow tools available in GitHub.
- Once you know your way around GitHub, register for and try out the course on Communicating Using Markdown. This is the lightweight formatting language that you can use in GitHub without the need to learn formal coding.
- The first thing you will use GH for is your pair task. There are instructions for forking (making your own version) the class repo (repository), and using a template to create your draft presentation at instructions_presenter.md .
- When you're ready to get feedback, follow the steps for a pull request (review) from a peer. The instructions for reviewing are at instructions_peer_reviewer.md. You'll be able to see the reviewer's comments and suggestions, and you can also use the *Issues* feature to raise specific questions or to respond to individual feedback items.

Advanced

- Log in to and register for and try out the course on Managing Merge Conflicts. You can use advanced GitHub features to make only specific changes in your documents.
- Use GitHub Project Management tools to assign tasks, create milestones, tag issues and requests to keep your work on track.

Resources for the group project - GitHub

master | Go to file | Add file | Code

eablack updated URL for webgrid … on 8 Aug 2019 224

Exersises	Create example-system-framework.…	3 years ago
presentations	Now a concrete instance	3 years ago
resources	updated URL for webgrid	3 years ago
site-analysis-task	Not really needed	3 years ago
.gitignore	Update .gitignore	3 years ago
Components.md	Update Components.md	3 years ago
Insights.md	Init	3 years ago
Interactions.md	align with use case	3 years ago
LDE-Stage2.md	corrections	3 years ago
Meeting-DDMM…	added file ending	3 years ago
Processes.md	Init	3 years ago
README.md	DEMO CHANGE	3 years ago
Roster.md	from roaster to roster, not rooster	3 years ago
Use-cases.md	demo file 1	3 years ago
contributing.md	spelling correction	3 years ago
differences-bet…	syntax fix	3 years ago

master | EDPC5022-2019 / Exersises / | Go to file | Add file | …

ech08ravo Create example-system-framework.md … on 2 May 2019 History

..		
Activity-diagram-examples.…	removed graphizo injection	3 years ago
Activity-diagram-exercise.md	copied from dev site	3 years ago
Control nodes with Dot.md	copied from dev site	3 years ago
Grapvizo-markup.md	no longer graphizo	3 years ago
activity-diagram-with-dot.md	copied from dev site	3 years ago
close-to-swimlanes.md	copied from dev site	3 years ago
ex0.md	copied from dev site	3 years ago
example-system-framewor…	Create example-system-framework.md	3 years ago
exercise-solutions-2.md	copied from dev site	3 years ago
exercise-solutions.md	copied from dev site	3 years ago


master
EDPC5022-2019 / resources /
Go to file
Add file
eablack updated URL for webgrid
on 8 Aug 2019
History
..
ActivityModels | fixed image | 3 years ago
images | an example workflow in a use case model | 3 years ago
Meeting-Knowledge-Templ... | some additions | 3 years ago
Productivity-demo-report.... | adjusting folders | 3 years ago
activation-syntax.md | Query on applying the activation rectangle in sequenc... | 3 years ago
activities-for-Meeting-Kno... | another embed option direct to raw svg to open in new... | 3 years ago
activities_overview.md | add png for easy viewing | 3 years ago
branching-demo.md | Moved into resources folder with other examples | 3 years ago
control-nodes-with-DOT.md | adjusting folders | 3 years ago
convergent-activities.md | forgot .md extension | 3 years ago
design-pattern-template.md | fixed the definition heading | 3 years ago
divergent-activities.md | updated URL for webgrid | 3 years ago
essay-template.md | adjusting folders | 3 years ago
evaluative-activities | swimlane graph of activities | 3 years ago
example-detailed-shared-... | detailed collab workflow example | 3 years ago
example-marpdown.md | adjusting folders | 3 years ago
example-roles-workflow.md | created example role-based workflow md with code & ... | 3 years ago
example-shared-approval-... | Example of how you might manage workflow with 2 ap... | 3 years ago
instructions-peer-reviewer... | adjusting folders | 3 years ago
instructions-presenter-slid... | How to create PDF from .md | 3 years ago
instructions_presenter.md | adjusting folders | 3 years ago
managing-merge-conflicts... | Folder name changes | 3 years ago
meeting-activities-guide.md | put separating lines between activities | 3 years ago
multiPAL-use-case.md | adjusting folders | 3 years ago
plant-uml.md | Visual Studion mention | 3 years ago
readings-overview.md | adjusting folders | 3 years ago
roles-and-responsibilities.... | replaced graph & code; minor typo | 3 years ago
semester-overview.md | adjusting folders | 3 years ago
site-analysis-template.md | URLs for component diagrams added | 3 years ago
structure-materials.md | adjusting folders | 3 years ago
student-presentation-moc... | added an image | 3 years ago
whats-my-graph.md | Fixed no space after markdown indicator | 3 years ago

master ▾ **EDPC5022-2019** / resources / **ActivityModels** / | Go to file | Add file ▾ | ···

eablack fixed image ··· on 25 Mar 2019 History

..		
3-12-3.md	fixed image	3 years ago
5-whys.md	simplified	3 years ago
affinity-map.md	removed redundant info	3 years ago
brainwriting.md	resources updated	3 years ago
card-sort.md	Beautified the md a bit	3 years ago
dot-voting.md	Beautified	3 years ago
forced-ranking.md	Beautified	3 years ago

master ▾ **EDPC5022-2019** / resources / **images** / | Go to file | Add file ▾ | ···

eablack an example workflow in a use case model ··· on 29 Mar 2019 History

..		
3-12-3.png	resources updated	3 years ago
3-12-3.svg	Update divergent.svg	3 years ago
5-whys.png	Copied from dev site	3 years ago
EDPC5022-example-com...	Create EDPC5022-example-community.png	3 years ago
EDPC5022-image.md	Copied from dev site	3 years ago
EDPC5022-roles-image.svg	Copied from dev site	3 years ago
EDPC5022-roles-v2.png	updated roles graph, fewer roles	3 years ago
EDPC5022-session-image....	Copied from dev site	3 years ago
EDPC5022_readings_imag...	Copied from dev site	3 years ago
RepGrid.png	table formatting insufficient	3 years ago
activities-guide.png	resources updated	3 years ago
activities-overview.png	Create activities-overview.png	3 years ago
activities-overview.svg	Create activities-overview.svg	3 years ago
affinity-map.png	Copied from dev site	3 years ago
brainwriting.png	resources updated	3 years ago
card-sort.png	resources updated	3 years ago
divergent.png	Create divergent.png	3 years ago
divergent.svg	Add files via upload	3 years ago
dot-voting.png	resources updated	3 years ago
example-activity.svg	Copied from dev site	3 years ago
example-case.png	Copied from dev site	3 years ago
example-component.png	Copied from dev site	3 years ago
example-workflow-roles.png	an example workflow in a use case model	3 years ago
forced-ranking.png	resources updated	3 years ago
graphviz-1.13-v16.dmg	Copied from dev site	3 years ago
meeting-activities.svg	clickable svg of design cycle	3 years ago
whats-my-graph.png	upload image file for subgraph tree	3 years ago

Appendix F

A detailed view of GitHub data

From the researcher's point of view, there are two views of GitHub data. The first is the same view as the students have; the graphical user interface (GUI) which displays web pages navigated by hyperlink clicks. These web pages display the documents and interactions in sections that have specific relevance to the software development workflow process for which GH was designed. These pages are designed to be read on screen, and data can not be exported from them, although uploaded documents can be downloaded and/or printed. They capture a temporal view of activity in the repository. An example of this GUI view is the top-level page of the repo for Team A at Figure A71 below. It shows folders containing the documents created by the team, for example *Meeting-Minutes*, actions performed by the team, for example, ***251*** *commits*, and interactions conducted by the team, for example *Issues.* Links from this top-level page in the GUI are navigated by the user to specific categories of event, for example, in the figure below, to pages listing *Issues*, *Pull Requests* and ***251*** *commits*. Each individual Issue, Pull Request and commit is an event. To view *commit* events in the GUI, clicking the word *commits* after ***251*** would display all commits in a series of pages, with further information accessible by clicking deeper links, as shown at Figure A72.

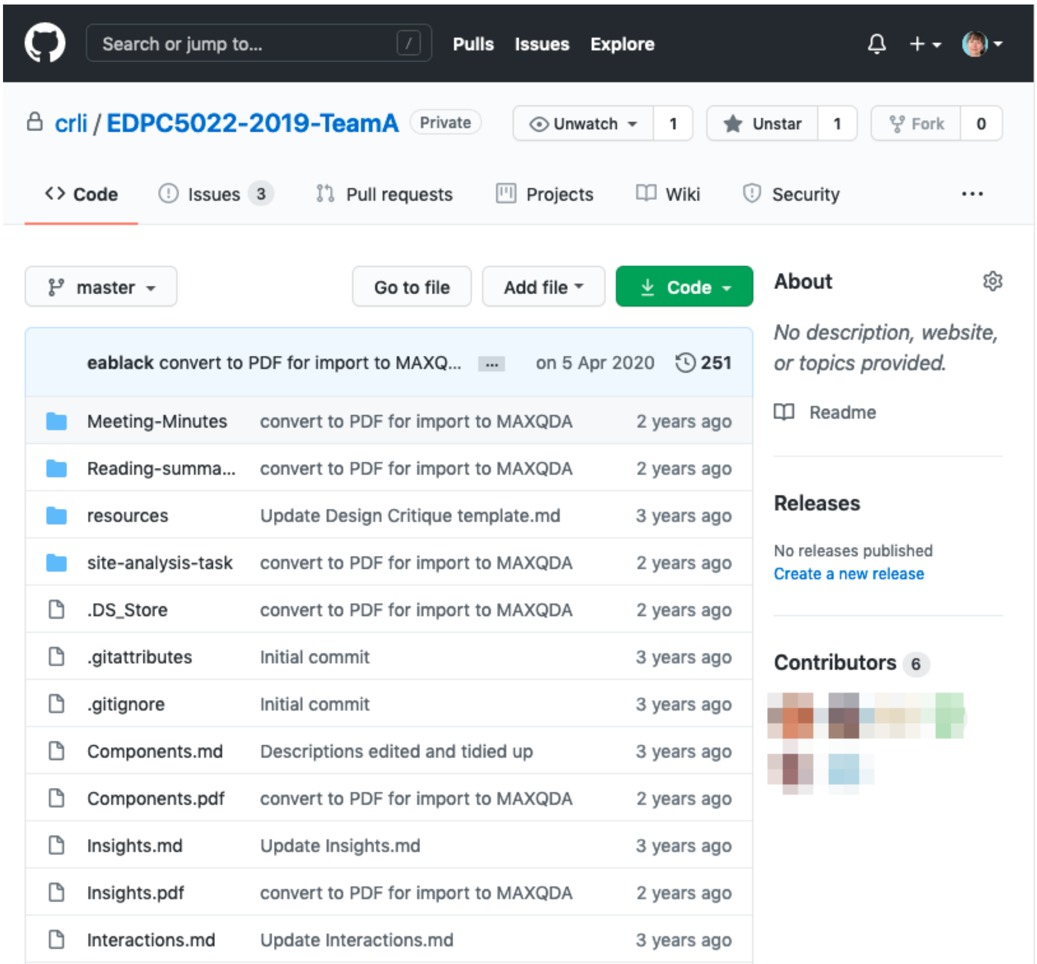


Figure A71: Partial screen shot of top level page for Team A's GitHub repository.

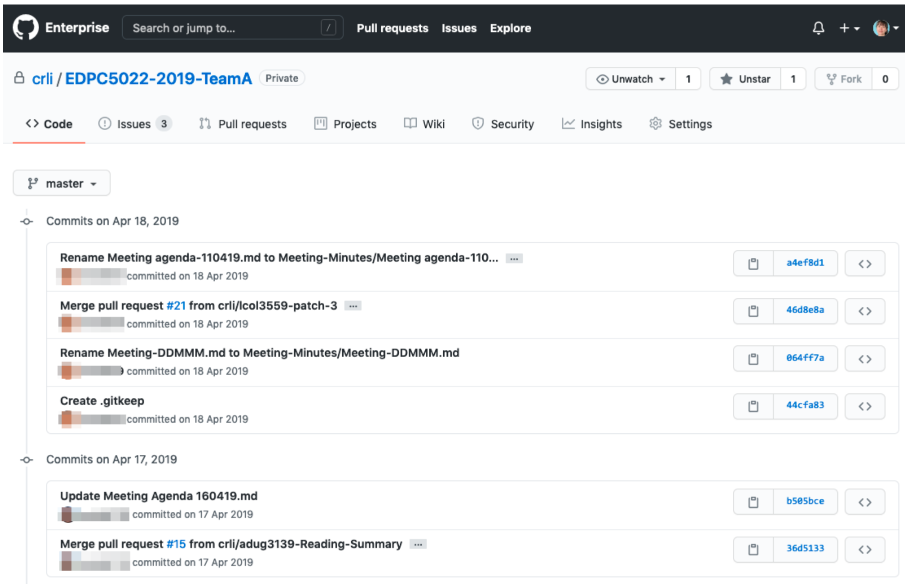


Figure A72: Commit events as shown through the GUI.

Using the GUI and click navigation, users can access data about activities in the repo contextualised to event type and timeframe. The display format collects related information and displays it in a conversational thread, for example, at Figure A73 below we can see Issue #39 in Team A's repo, and the series of events that occur after it is opened on 2 May 2019.

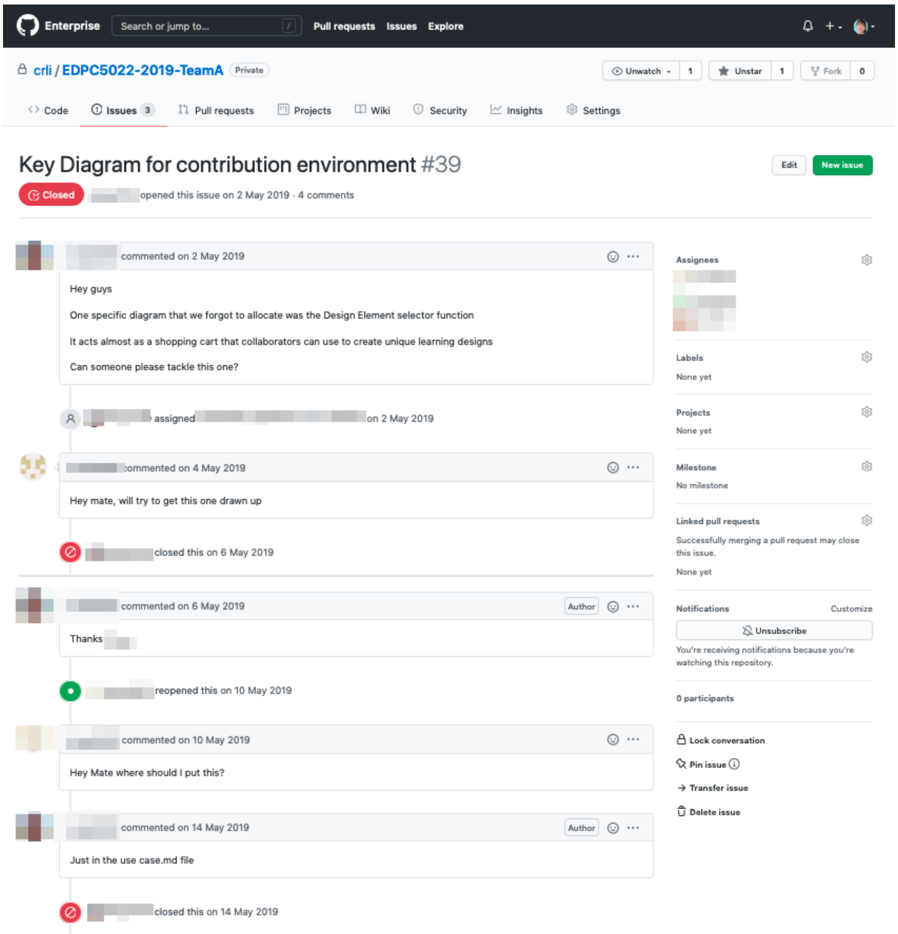


Figure A73: Partial screenshot from Team A's repo showing Issue A#39 conversation.

GitHub contains sophisticated software development and workflow features which are not superficially obvious and not all enabled in our Enterprise version. The features used by students in the study are listed below, along with a short description of their intended purpose in the GitHub workflow (GitHub.com, 2020a, 2020b, 2021b), at Table A39. Each team's GitHub repo was downloaded from the university's system, Issues, Pull Requests and final document versions were printed from the GUI to PDF, and all data uploaded to the university's Research Data Store and a copy made on the researcher's local computer for coding and analysis. The repos were still available live on the GH server for use during the analysis process.

*Table A39: Data available in the GH environment. * indicates the data is only human-readable through the GUI or accessible on an individual issue basis.*

GH object or event	What it is/does
Commit	Save changes to a document, for example, to a use-case model.
Commit message (title & comment)	Describe changes made in the commit.

GH object or event	What it is/does
Pull Request	Request review of a comparison of changes and merge into the master (shared) branch.
@mention	Alert specific team member to the event (can be used across all events).
Pull Request message (title & comment)	Describe changes made in the commit.
Pull Request comment	Provide feedback on a pull request
Merge	Accept changes and incorporate them into the master (shared) branch.
Issue	Track tasks, enhancements and bugs.
Issue message (title & comment)	Provide feedback on an issue.
Assign	Delegate responsibility to a team member.
Reference	Hyperlink to associated issue or pull request.
Request review	Ask for feedback on a change.
Review comment*	Provide direct feedback in-text on document changes.
Approval comment*	Provide direct feedback on approval request.
Diff*	Highlighted view of added, edited and deleted code to facilitate comparison.
Document version*	State of document at a particular point.
History*	Timeline of a specific issue or pull request.

The second view of the data is through the GitHub REST API. This term refers to an Application Programming Interface (API) that conforms to a specific architecture for a representational state transfer (REST) (Red Hat, 2020). Using the REST API requires establishing a secondary authentication method to the Enterprise GH system, and accessing each groups' repo using the command line, that is, typing instructions into a terminal-type interface rather than using a point-and-click method. In this case, the OAuth code grant type (GitHub.com, 2021a) was used to authorise remote calls to the server, which provided a personalised 'token' required for each request for information. The University's Virtual Private Network (VPN) was also required to be active for additional security during each server access.

Once the security measures had been established, a separate 'call', or request, was required for each piece of information sought. As this was a novel research data source, a wide net was cast for all events that might prove to be useful sources for interaction data. As the GitHub environment is primarily a software development environment where code contribution frequency and volume is a success metric, events such as *branches*, *forks* and *punch card* (a count of commits per hour per day) were available and their data downloaded, but analysis was not conducted on them as they relate specifically to workflow features that were not mandated in the project and were used inconsistently within and across groups. The data that was downloaded and subjected to analysis is in black at Table A40, with the associated API call. Data that was downloaded and not analysed is in grey. Data relating to team member contributions did not include Issues, Pull Requests or comments, so it was discarded and contributions manually calculated by the researcher.

Table A40: GitHub event data accessible through API calls with associated command-line input.

GH object or event	What it is/does	API call
branches	list all branches in repo	wget --header "Authorization: Bearer d7f76f8fb0cdcb7f7d0864a87aebf135c5a120e6" "https://github.sydney.edu.au/api/v3/repos/crli/EDPC5022-2019-TeamC/branches"
code frequency	count of code additions and deletions each week	wget --header "Authorization: Bearer d7f76f8fb0cdcb7f7d0864a87aebf135c5a120e6" "https://github.sydney.edu.au/api/v3/repos/crli/EDPC5022-2019-TeamC/stats/code_frequency"
comment	count of comments on commit or Issue BUT NOT approval, Pull Request or review	wget --header "Authorization: Bearer d7f76f8fb0cdcb7f7d0864a87aebf135c5a120e6" "https://github.sydney.edu.au/api/v3/repos/crli/EDPC5022-2019-TeamC/issues/comments"
commits	count of new files or changes to files	wget --header "Authorization: Bearer d7f76f8fb0cdcb7f7d0864a87aebf135c5a120e6" "https://github.sydney.edu.au/api/v3/repos/crli/EDPC5022-2019-TeamC/commits"
contents	list all files in repo	wget --header "Authorization: Bearer d7f76f8fb0cdcb7f7d0864a87aebf135c5a120e6" "https://github.sydney.edu.au/api/v3/repos/crli/EDPC5022-2019-TeamC/contents"
contributors	count of commits, issues and Pull Requests by person BUT NOT comments	wget --header "Authorization: Bearer d7f76f8fb0cdcb7f7d0864a87aebf135c5a120e6" "https://github.sydney.edu.au/api/v3/repos/crli/EDPC5022-2019-TeamC/contributors"
forks	count of repo forks created	wget --header "Authorization: Bearer d7f76f8fb0cdcb7f7d0864a87aebf135c5a120e6" "https://github.sydney.edu.au/api/v3/repos/crli/EDPC5022-2019-TeamC/forks"
issue events	list all events associated with any issue	wget --header "Authorization: Bearer d7f76f8fb0cdcb7f7d0864a87aebf135c5a120e6" "https://github.sydney.edu.au/api/v3/repos/crli/EDPC5022-2019-TeamC/issues/events"
issues	list all issues	wget --header "Authorization: Bearer d7f76f8fb0cdcb7f7d0864a87aebf135c5a120e6" "https://github.sydney.edu.au/api/v3/repos/crli/EDPC5022-2019-TeamC/issues"

GH object or event	What it is/does	API call
participation	count of all commits in current week by person	wget --header "Authorization: Bearer d7f76f8fb0cdcb7f7d0864a87aebf135c5a120e6" "https://github.sydney.edu.au/api/v3/repos/crli/EDPC5022-2019-TeamC/stats/participation"
pull comments	list all comments associated with any pull request	wget --header "Authorization: Bearer d7f76f8fb0cdcb7f7d0864a87aebf135c5a120e6" "https://github.sydney.edu.au/api/v3/repos/crli/EDPC5022-2019-TeamC/pulls/comments"
pulls	list all pull requests	wget --header "Authorization: Bearer d7f76f8fb0cdcb7f7d0864a87aebf135c5a120e6" "https://github.sydney.edu.au/api/v3/repos/crli/EDPC5022-2019-TeamC/pulls "
punch card	count of number of commits per hour per day	wget --header "Authorization: Bearer d7f76f8fb0cdcb7f7d0864a87aebf135c5a120e6" "https://github.sydney.edu.au/api/v3/repos/crli/EDPC5022-2019-TeamC/stats/punch_card"

Three additional parameters were necessary, depending on the type of event and the number of events in the repo. First, a "status=all" parameter is required for all events that have a possible status, to capture events that are closed, open, or have another status. Second, a page number is necessary for those events whose number may exceed the default page size of 30 events, and to reduce the number of calls that need to be made, increasing the page size to the maximum of 100 events is also useful. So, to list all Issues regardless of status, where there are, say, 150 issues requires two calls. The first would be:

```
wget --header "Authorization: Bearer
d7f76f8fb0cdcb7f7d0864a87aebf135c5a120e6"
"https://github.sydney.edu.au/api/v3/repos/crli/EDPC5022-2019-
TeamC/issues?state=all&per_page=100&page=1"
```

And the second:

```
wget --header "Authorization: Bearer
d7f76f8fb0cdcb7f7d0864a87aebf135c5a120e6"
"https://github.sydney.edu.au/api/v3/repos/crli/EDPC5022-2019-
TeamC/issues?state=all&per_page=100&page=2"
```

Each page number must be manually incremented until the number of Issues (or whichever event is being called) is exhausted, which is visible through observing the output size. For example, we can see the data output below shows page 12 of issue events has a file size around 434KB, meaning it contains quite a lot of data:

> events?per_page=100&page=12
> 100%[===>] 434.08K -
> -.-KB/s in 0.08s
> 2021-06-30 17:59:04 (5.04 MB/s) - ‘events?per_page=100&page=12’ saved
> [444502/444502]

Whereas when we output page 13 of issue events, the file size is only 5KB, around the minimum block size on my Mac file system for my hard disk size. This indicates an empty file, and time to stop downloading this event type.

> events?per_page=100&page=13
> 100%[===>] 5 --.-
> KB/s in 0s
> 2021-06-30 17:59:07 (44.0 KB/s) - ‘events?per_page=100&page=13’ saved [5/5]

The output is in the JavaScript Object Notation (JSON) lightweight data interchange format, which can be converted to other formats for manipulation. When converted to comma-separated values (csv), the same commit even data shown in the GUI at Figure A72 above is represented in the form shown at Figure A74, which has had a number of columns hidden and others shaded for ease of reference in this illustration.

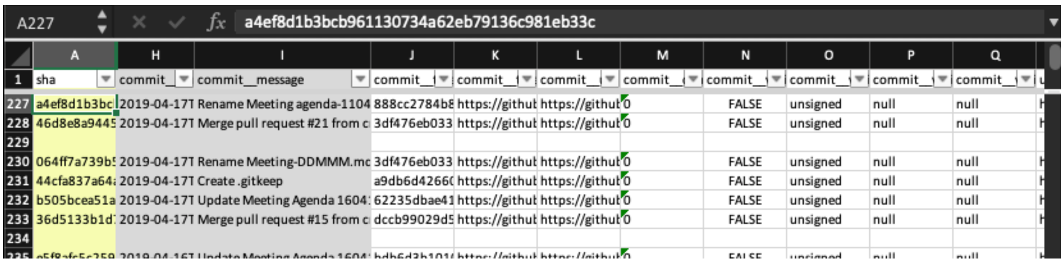


Figure A74: Commit events as shown through data output using the API.

Appendix G

Meeting notes template

master ▾ **EDPC5022-2019** / resources / **Meeting-Knowledge-Template.md** Go to file ···

some additions Latest commit 272ff52 on 3 Apr 2019 **History**

2 contributors

Executable File | 80 lines (44 sloc) | 4.14 KB Raw Blame

Meeting Knowledge template v0.1

The purpose of this document is to manage meetings and the knowledge that is created in them. Create one such document per meeting, minimally one per project week.

Meeting Agenda (Facilitator)

Date/Time: goes here

In attendance: names go here

Facilitator: Name goes here

Knowledge Manager: Name goes here

A. Topics/Goals

1. top 1
2. top 2
3. (...)

B. Activities (Facilitator)

(Activities are not identical to topics: Activities contribute to achieving topics, which are usually seen as goals.)

Activity 1

Duration (in minutes):

Describe activity, link to resources etc.:

Lorem ipsum dolor sit amet, consetetur sadipscing elitr, sed diam nonumy eirmod tempor invidunt ut labore et dolore magna aliquyam erat, sed diam voluptua. At vero eos et accusam et justo duo dolores et ea rebum. Stet clita kasd gubergren, no sea takimata sanctus est Lorem ipsum dolor sit amet.

Activity 2

Duration (in minutes):

Describe activity, link to resources etc.:

Lorem ipsum dolor sit amet, consetetur sadipscing elitr, sed diam nonumy eirmod tempor invidunt ut labore et dolore magna aliquyam erat, sed diam voluptua. At vero eos et accusam et justo duo dolores et ea rebum. Stet clita kasd gubergren, no sea takimata sanctus est Lorem ipsum dolor sit amet.

Activity 3

Duration (in minutes):

Describe activity, link to resources etc.:

Lorem ipsum dolor sit amet, consetetur sadipscing elitr, sed diam nonumy eirmod tempor invidunt ut labore et dolore magna aliquyam erat, sed diam voluptua. At vero eos et accusam et justo duo dolores et ea rebum. Stet clita kasd gubergren, no sea takimata sanctus est Lorem ipsum dolor sit amet.

Follow up actions (Facilitator, Knowledge Manager)

(Formulate action items as issues (connected to milestones) and link to these using their GitHib.)

- [ ] short description and link to issue
- [ ] Action different from an issue
- [ ] (...)

Additional notes taken during the meeting (Knowledge Manager, Facilitator)

(Everything worth mentioning from the meeting that does not fit into the points above.)

Lorem ipsum dolor sit amet, consetetur sadipscing elitr, sed diam nonumy eirmod tempor invidunt ut labore et dolore magna aliquyam erat, sed diam voluptua. At vero eos et accusam et justo duo dolores et ea rebum. Stet clita kasd gubergren, no sea takimata sanctus est Lorem ipsum dolor sit amet. Lorem ipsum dolor sit amet, consetetur sadipscing elitr, sed diam nonumy eirmod tempor invidunt ut labore et dolore magna aliquyam erat, sed diam voluptua.

At vero eos et accusam et justo duo dolores et ea rebum. Stet clita kasd gubergren, no sea takimata sanctus est Lorem ipsum dolor sit amet. Lorem ipsum dolor sit amet, consetetur sadipscing elitr, sed diam nonumy eirmod tempor invidunt ut labore et dolore magna aliquyam erat, sed diam voluptua. At vero eos et accusam et justo duo dolores et ea rebum. Stet clita kasd gubergren, no sea takimata sanctus est Lorem ipsum dolor sit amet.

Notes from the meeting recording (Knowledge Manager)

(Everything worth mentioning from the meeting that does not fit into the points above.)

Link to the recording:

timestamp of relevant interaction Lorem ipsum dolor sit amet, consetetur sadipscing elitr, sed diam nonumy eirmod tempor invidunt ut labore et dolore magna aliquyam erat, sed diam voluptua. At vero eos et accusam et justo duo dolores et ea rebum. Stet clita kasd gubergren, no sea takimata sanctus est Lorem ipsum dolor sit amet. Lorem ipsum dolor sit amet, consetetur sadipscing elitr, sed diam nonumy eirmod tempor invidunt ut labore et dolore magna aliquyam erat, sed diam voluptua.

timestamp of relevant interaction At vero eos et accusam et justo duo dolores et ea rebum. Stet clita kasd gubergren, no sea takimata sanctus est Lorem ipsum dolor sit amet. Lorem ipsum dolor sit amet, consetetur sadipscing elitr, sed diam nonumy eirmod tempor invidunt ut labore et dolore magna aliquyam erat, sed diam voluptua. At vero eos et accusam et justo duo dolores et ea rebum. Stet clita kasd gubergren, no sea takimata sanctus est Lorem ipsum dolor sit amet.

end

Appendix H

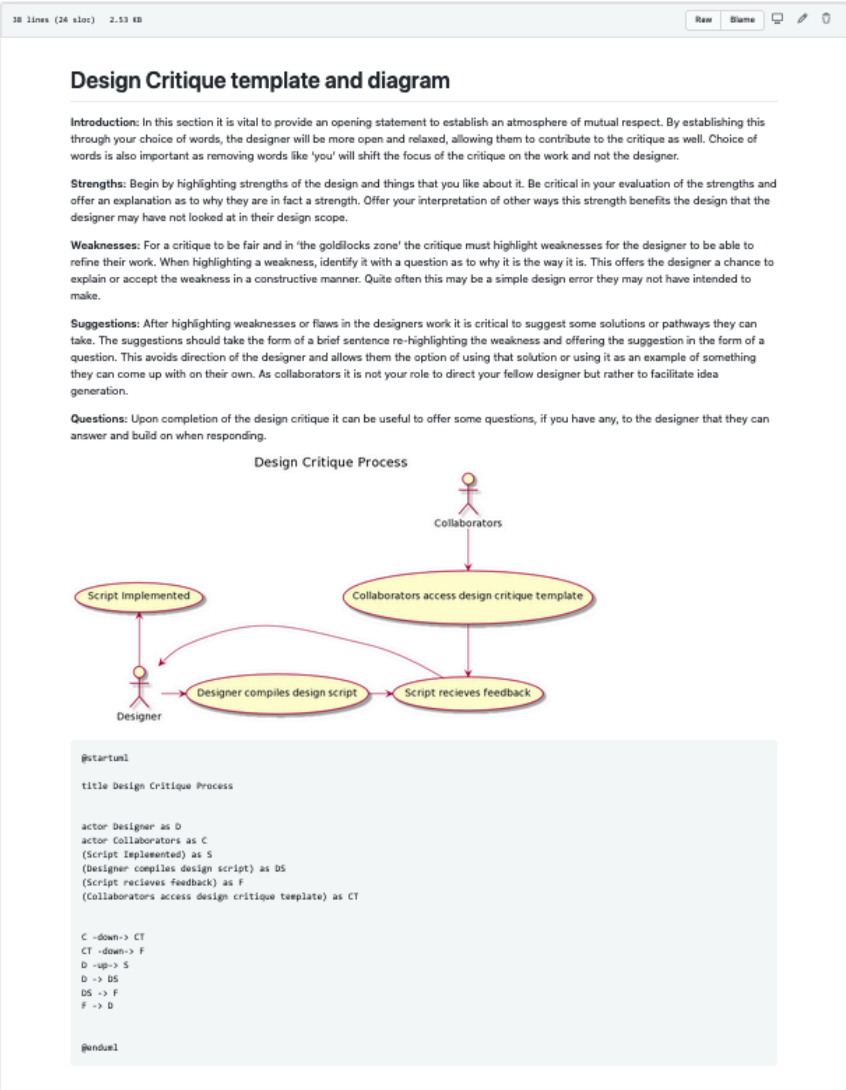
Additional excerpts from interaction data

Collaborative characteristics of GitHub actions/interactions: Team A

Epistemic dimension of actions

Alleviating lack of knowledge

There was an occasion where a team member went toward engaging the entire group in gaining deeper theoretical understanding, providing a structured template for the conduct of a Design Critique at comment 1356 and illustrated at Figure A75 below, in response to the instructor-initiated task. The model comprises a narrative, diagram and code suitable for a system implementation but without academic foundation for the critique process. The two team members providing their critique after the template link was posted followed most of the bolded steps in the narrative section.


38 lines (24 sloc) 2.53 KB

Raw Blame

Design Critique template and diagram

Introduction: In this section it is vital to provide an opening statement to establish an atmosphere of mutual respect. By establishing this through your choice of words, the designer will be more open and relaxed, allowing them to contribute to the critique as well. Choice of words is also important as removing words like 'you' will shift the focus of the critique on the work and not the designer.

Strengths: Begin by highlighting strengths of the design and things that you like about it. Be critical in your evaluation of the strengths and offer an explanation as to why they are in fact a strength. Offer your interpretation of other ways this strength benefits the design that the designer may have not looked at in their design scope.

Weaknesses: For a critique to be fair and in 'the goldilocks zone' the critique must highlight weaknesses for the designer to be able to refine their work. When highlighting a weakness, identify it with a question as to why it is the way it is. This offers the designer a chance to explain or accept the weakness in a constructive manner. Quite often this may be a simple design error they may not have intended to make.

Suggestions: After highlighting weaknesses or flaws in the designers work it is critical to suggest some solutions or pathways they can take. The suggestions should take the form of a brief sentence re-highlighting the weakness and offering the suggestion in the form of a question. This avoids direction of the designer and allows them the option of using that solution or using it as an example of something they can come up with on their own. As collaborators it is not your role to direct your fellow designer but rather to facilitate idea generation.

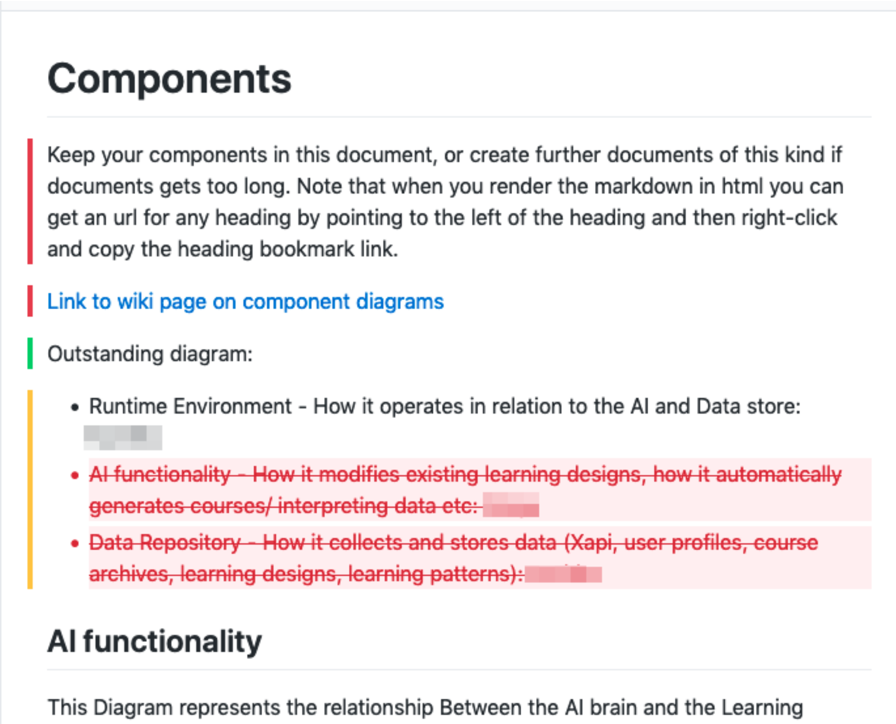
Questions: Upon completion of the design critique it can be useful to offer some questions, if you have any, to the designer that they can answer and build on when responding.


```
@startuml

title Design Critique Process


actor Designer as D
actor Collaborators as C
(Script Implemented) as S
(Designer compiles design script) as DS
(Script recieves feedback) as F
(Collaborators access design critique template) as CT


C -down-> CT
CT -down-> F
D -up-> S
D -> DS
DS -> F
F -> D


@enduml
```

Figure A75: Screen shot showing template created by a team member for use in the instructor-initiated design critique task.

General collaborative actions

Approaching the collaboration through task division is observable, at a first level in the documents themselves, where on occasions they noted where work was outstanding by noting it in the relevant document, for example, at commit 8d73137 on Components.md shown at Figure A76.



Components

Keep your components in this document, or create further documents of this kind if documents gets too long. Note that when you render the markdown in html you can get an url for any heading by pointing to the left of the heading and then right-click and copy the heading bookmark link.

Link to wiki page on component diagrams

Outstanding diagram:

- Runtime Environment - How it operates in relation to the AI and Data store:
- ~~AI functionality - How it modifies existing learning designs, how it automatically generates courses/ interpreting data etc:~~
- ~~Data Repository - How it collects and stores data (Xapi, user profiles, course archives, learning designs, learning patterns):~~

AI functionality

This Diagram represents the relationship Between the AI brain and the Learning

Figure A76: Partial screenshot of group tracking development progress through annotation in a shared knowledge object.

There were occasions where a team member's contribution was done only partially, was not provided, or was provided to a lower standard because of a lack of understanding which had not been addressed through searching for information or asking others. For example, two team members expressed lack of knowledge around constructing UML diagrams. In the first instance, when another team member expresses frustration that work has not been completed, A4 at Issue A#29[1] apologises for "going off the grid" and expresses confusion about translating his ideas into UML models, reiterating the struggle he expressed at a previous commit b31324c. A1 asks him to post the drawing and code, which he does in the next two comments, shown at Figure A77.

[1] In this section, comments have a four-digit identifier, commits a seven-character identifier, Issues and Pull Requests have a team identifier, followed by a "#" symbol and the Issue or Pull Request identifier.

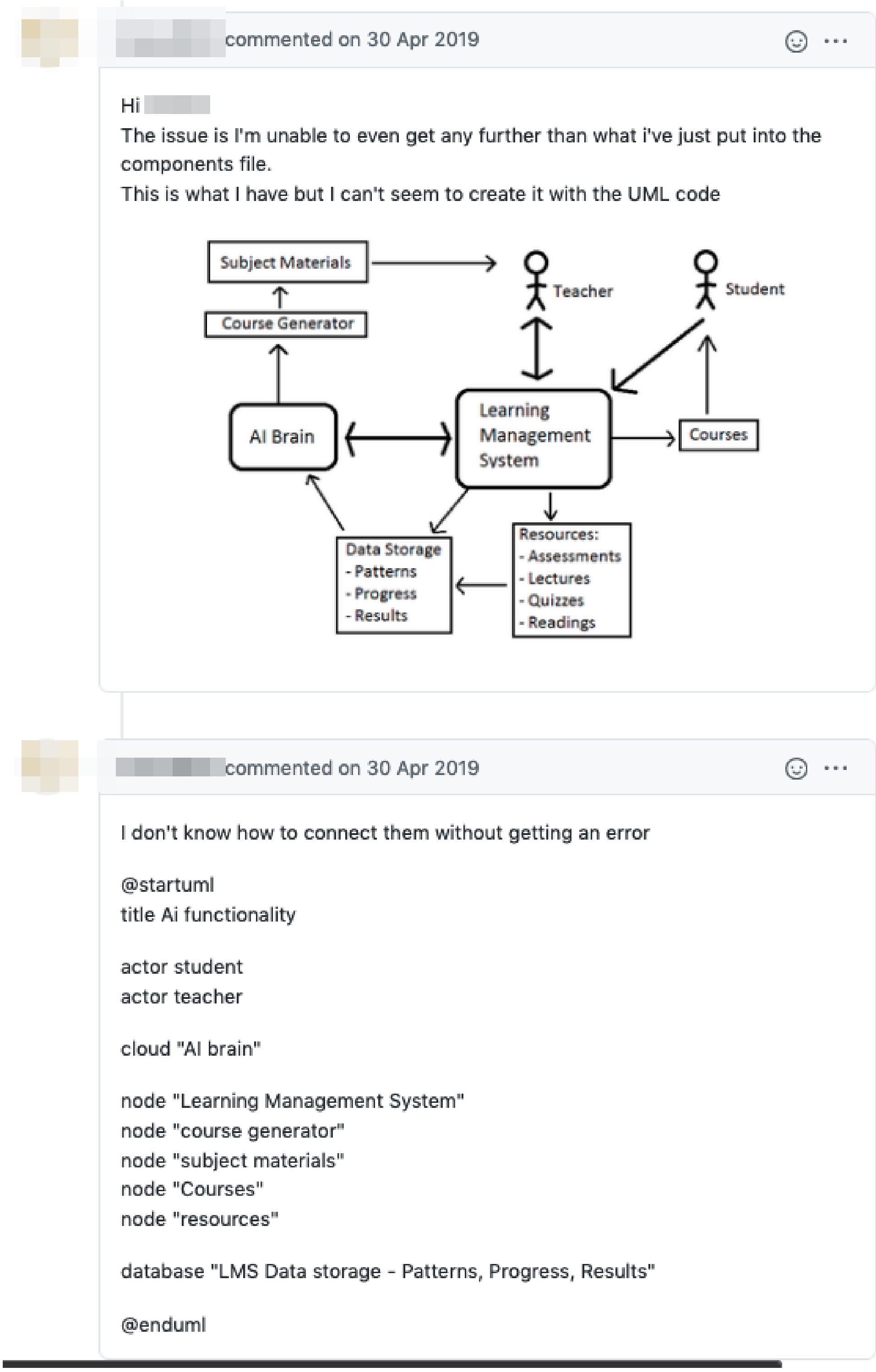


Figure A77: Comment from A4 at Issue #29 about problems constructing UML diagram.

It is notable that A4 does not mention whether any strategies they have tried to resolve the problem, as we have seen that one advantage of UML coding is that a mistake in the syntax will generate an error specific to the location and type of the error. They also do not mention any problem-solving strategies such as searching the repo or online resources to find out how to add the lines of code that draw the arrows from one component to the other. If we attempt to generate a model from the code he has pasted, as shown at Figure A78, the code itself after @startuml is valid, but contains no attempts at connection.

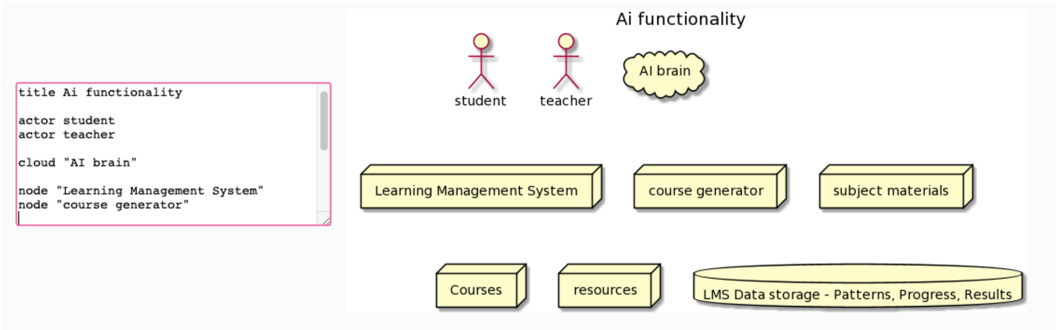


Figure A78: UML diagram generated from code posted in Issue #29.

Following the offer by A1 to look at A4’s diagram, A3 pasted a flowchart at comment 1260 followed by “Please see the diagram.. I have tried to do it in UML but I guess old powerpoint tools seems to work for me.. I will try UML again..”, as shown at Figure A79. A3 also does not mention what they have tried so far and what has not worked.

While there does not appear to be a response to A3’s posting of their flowchart, A1’s response to A4’s struggle with UML code is to simply create the diagram for him, without describing the steps they took to resolve the missing arrows, commenting at #38 “Update Components.md @A4 I've tried to help you out with your diagram. I didn't want to mess with anything you had already done so I've just added it below. Please feel free to use/ignore as you'd like. Cheers, [A1]”.

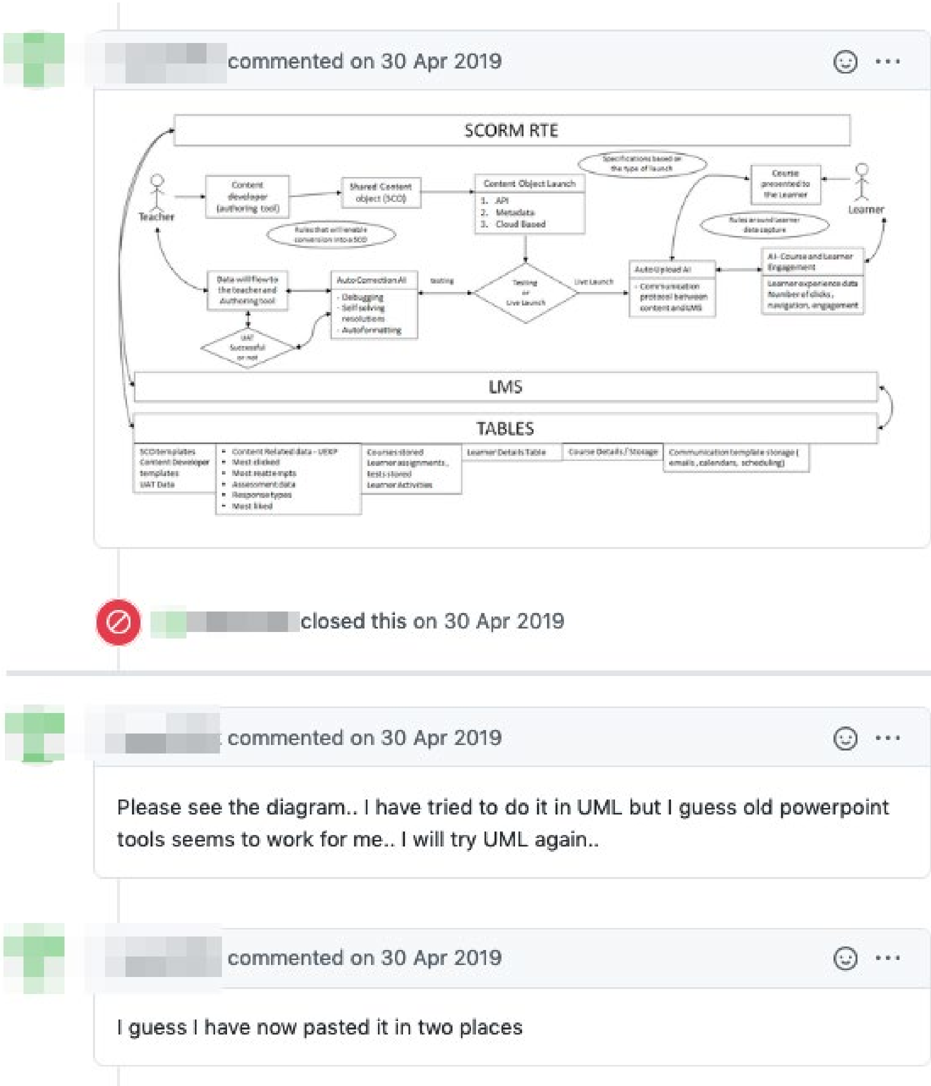


Figure A79: Comment from A3 at Issue #29 about problems constructing UML diagram.

Interestingly, three days later at issue #31, A3 posts two well-formed UML use case diagrams that are more relevant to the task without any comment at all. A4 also works it out eventually; at commit 2211347 celebrating with "…I finally figured out how to create a simple UML diagram".

Table A41 provides examples of Team A's feedback practices, indicating a general approach where knowledge objects or collaborative processes were provided as conclusive. There were two exceptions early in the collaboration, both relating to document merge and location processes: commit comment 9f2ad46 "I think they should be added to the master branch", and comment 11154 relating to *README.md* "I think it would be a good idea to consolidate it under Insights.md".

Table A41: Excerpts from GitHub interaction data showing Team A discussion around tasks and processes.

Reference	Comment
9f2ad46	Check out the draft roster, if everyone's happy with the proposed schedule then we can commit it to the master branch.
A#7	Yeah I think we have time allocated after the presentations to work on this task but since it's only a short period I think we will reconvene on the Thursday if everyone is happy with this.
59a69ed	It's still a work in progress, but feel free to update as you see fit!
A#22	Hi All, Just advising that I've created a "Meeting Minutes" folder and moved all our existing minutes into it. I was sort of doing it by trial and error and skipped the pull request step. If anyone wants me to undo and move everything back to the main repo, let me know!
A#24	If you are happy with this, please merge into the master!
1261	Please see the diagram..
A#38	Please feel free to use/ignore as you'd like.

After a narrative, diagram or code had been committed to a document, it was rarely altered except to address technical errors in display or editing. For example, as part of the instructor-initiated Design Critique of Team A's interactions.md model, two team members identified the unlimited data storage timeframe as a design limitation and suggested the addition of a reduced storage period (comment 1299 and 1407). This change was not made, nor were any other recommended modifications.

Regulative dimension of actions

Projective

We can see efforts to find information from each other about the shared space and about the task which continued throughout the team project, illustrated at Table A42, but we can't see examples of discussing their approach to the project or their approach to making decisions about how to work together.

Table A42: Excerpts from GitHub interaction data showing individual efforts to add to the shared knowledge objects.

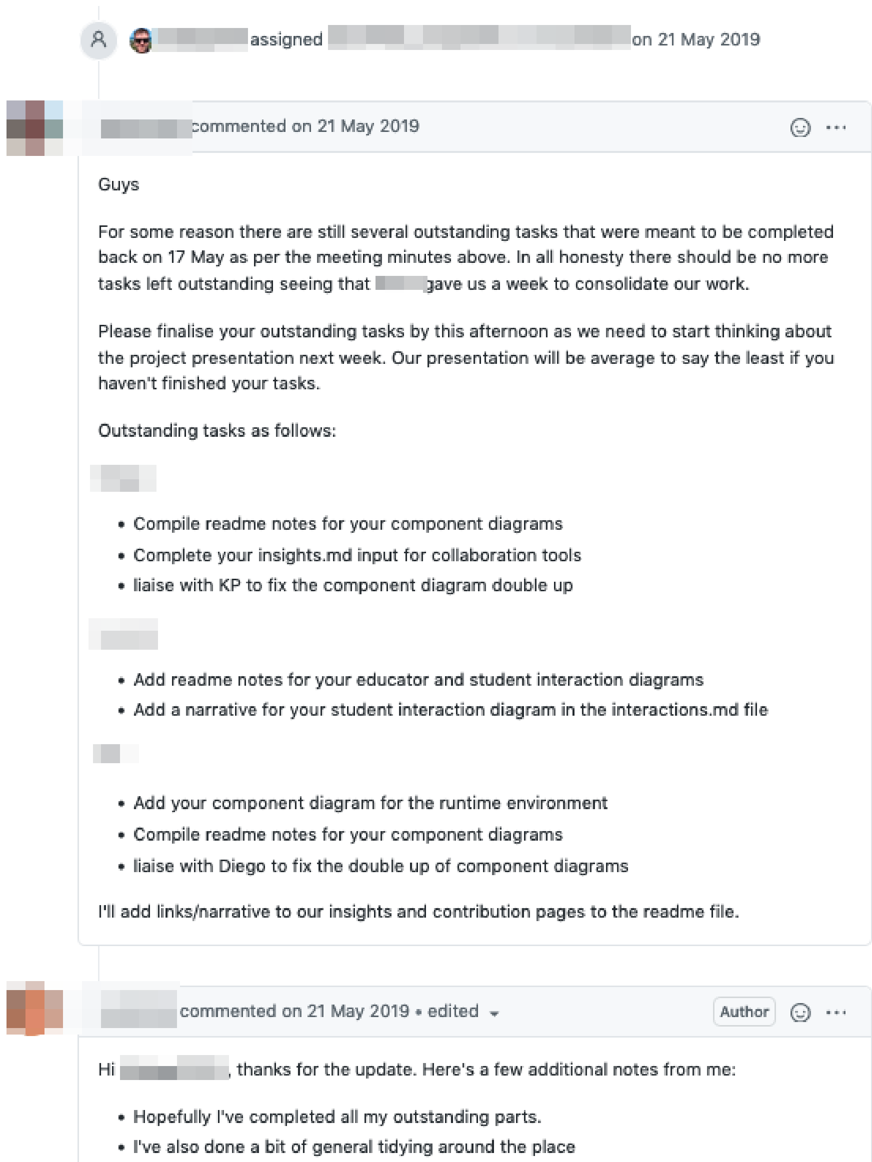
Reference	Comment
A#8	Is this the right place?
A#17	is this the best way to update content that hasn't been merged?
A#30	Is this what we needed?
2211347	is this the right place for this?
1356	Which file should I link this to?
A#39	Hey Mate where should I put this?
A#49	is this the right place for this?

Develop a structured knowledge object approval process

Early in the project we see examples of shared decision making on document construction around the setting up the project with review requested of the roster (A#5) first meeting agenda (A#13), draft process document (A#8, A#12) and repo README (A#10). However, this method was not sustained for the duration of the collaboration. There are only five further occurrences of team-based approval, associated with specific needs either unexpressed. for example, A#27 Learning Design Interaction Diagram, a request with no associated communication, or explicit, for example, A#37 the Design Critique instructor task. On two occasions team members requested review on their diagrams, one without any communication (A#33 A3) and one asking whether it was in the correct location (A#49 A4). The other occurrence of a request for review was when one team member assisted another by creating a document to properly locate and format their reading summary which had been pasted as text into a comment, and asked them to check it (A#24).

Regulative

Figure A80 shows comments indicate that team members focus on their 'assigned' parts, and in the case of the 'double up' referred to at #A51, it is resolved by another team member with no mention of discussing it with the team member who contributed the diagram.



-- figure continues next page

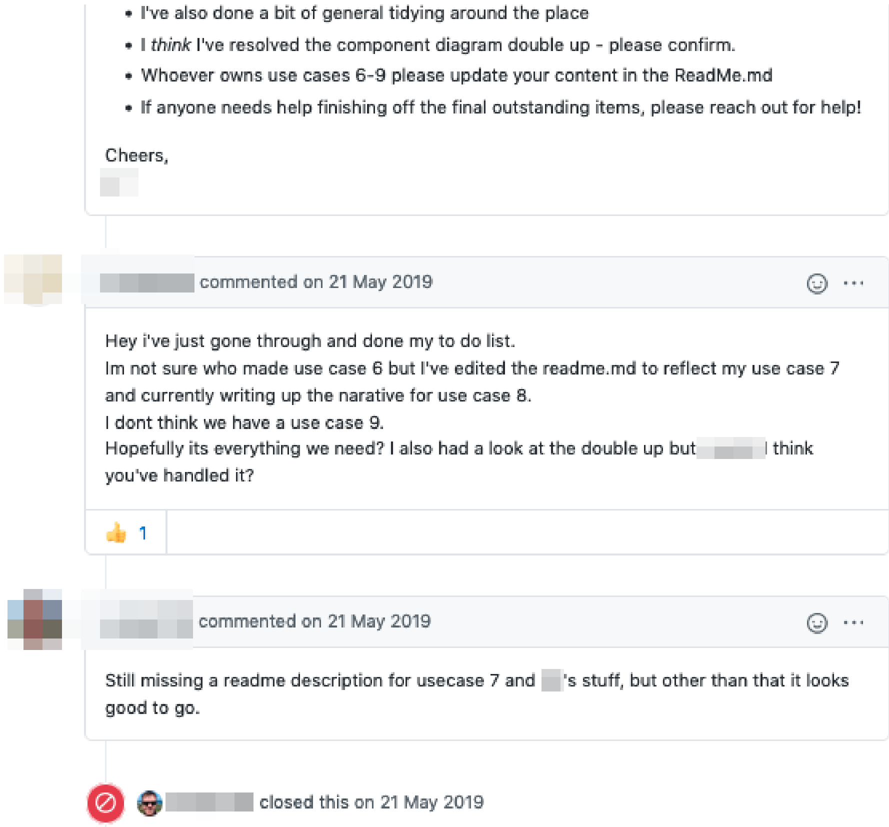


Figure A80: Partial screen shot from Issue A#46 illustrating Team A's interactions around task finalisation.

Monitoring work in development did not appear systematic, for example, before the Easter break A2 raises Issue #29, asking “Hey team Where are all the other diagrams that were meant to be completed on Friday? All I can see are the two that Lauren and I put together.”. However, at the same time, their next comment 1201 is they will not attend that week’s meeting “if there’s any scheduled”. This was followed by another team member setting out the assignment of diagrams to team members, and noting at comment 1202 that “If everyone completes their required diagrams I think we may be set for this week and not need to meet - does anyone feel otherwise?”.

At the recommencement of classes, A1 raises Issue #30 commenting “Hi All, Hope you had a lovely uni-free week! I am just checking in as we still have a fair few outstanding tasks that have been delegated. I'll be putting together an agenda for our next meeting sometime today, but in the interim can everyone please provide a **brief status update** and identify any **roadblocks/concerns** they are having? That way we can try and tackle them as a group when we catch up. Cheers, Lauren”. However, the interaction data does not support a shared monitoring of the state of the design product, with the first response at comment 1247 “Hey Lauren I've knocked over my assigned task and updated my interaction diagram to include actions along the timeline of each object. I'm not sure where the others are at seeing everything was due the other week.”. This way of working continues closer to submission date, with similar messages and responses at Issue #46 in Week 11.

When additional work was required, the interactions around it are ad hoc, with a general call for a volunteer to complete the task alone the way of managing the collaboration, with varying degrees of indirectness as illustrated at Table A43 below.

Table A43: Excerpts from GitHub interaction data showing Team A discussion around the state of the knowledge object/s.

Reference	Comment
A#14	Can someone compile a narrative (this just needs to be a description of the diagram with an academic spin).
A#39	Can someone please tackle this one?
A#51	Guys I don't know what has occurred in the component.md page but it looks like KP has duplicated her component diagram. Can you please take a look and rectify the issue ASAP.
A#29	For anyone who hasn't had a look at the minutes, diagrams have been assigned as follows:
A#16	As stated in the pull requested outlined below are notes to help with the creation of the use case diagram narrative…That basically the gist of what i came up with, please expand on the notes to create a detailed narrative.
5a86a7a	The macro level diagram also needs a narrative.

Collaborative characteristics of GitHub actions/interactions: Team B

Epistemic dimension of actions

Alleviating lack of knowledge

Team B looked for shared insights around the collaborative environment, asking for help in some cases directly, as in B#17 and B#18 above, or indirectly as in commit 0633644 "I've added a description of the use case and a planttext diagram. Feel free to amend,- does anyone know how to change it from horizontal display to vertical?" and Issue #52 "I realise my fix on image didn't work- can anyone help? Looks fine, but not displaying.". There are also examples of interactions that appear intentional sharing of useful information. For example, at commit b68eab0, "I had to copy & paste the branch back into the master- couldn't work our easier way. This is now incorporating all our changes", where B4 is sharing knowledge about how to use the environment as well as reporting what's been done to incorporate everyone's work, and commit 784c2e "Removed space to fix display", another attempt to correct the code syntax to make a diagram display inline. In other commits, the goal without the method was in the comment, for example, at ff7fd78 "fixed display of heading 3 took it out of the grey box" describes an edit where backticks were inserted into the code syntax to mark the end of a code sequence, resulting in the heading in the next line displaying correctly. Other specific examples of sharing environment and task knowledge are below at Table A44.

Table A44: GitHub comments indicating sharing insights with others.

Reference	Comment
3fc3458	Fix typos and generate Use case 3 image I fixed the uml so the image would display properly.
B#13	Attempting to fix the diagram here.
56ea217	fixed diagram display I removed the space between the](to make the image display properly.
f1d59a1	added bullets to list i changed the display so the use cases are listed as a bulleted list.

Team B showed elements of organising and structuring their knowledge . At B#44, B5 asks team members to "Please add files, links or names of pedogogical research that supports our scenarios / 2025 vision.". At comment 1253, B6 linked to a Word document containing quotes copied and pasted from an educational technology report, and questions for consideration in the group's design, for example, "Do we need to have a function within our learning platform where teachers can simply upload audio in response to learner's questions???", and "??? Does it matter what sort of educational institution we are designing for? Will this change the way we design?", and we can tell from comment 1276 that that at least one other team member thought this an "interesting starting point to consider". However, there is no further mention or evidence of these resources being used after their creation.

Creating shared understanding

As well as working on knowledge objects after them, we can also see that Team B planned to discuss their knowledge objects in group meetings, as shown by the comments at Table A45

Table A45: Excerpts from GitHub interaction data showing intention to discuss draft knowledge objects at team meetings.

Reference	Comment
1379	Not sure where this all leads us... no specific amends suggested by perhaps discuss on Tues/next meeting?
1486	Thank you [B2]. I agree that we should look at both of them together on Tuesday.
1505	Be good if we could revisit anything I missed in our meeting tonight.

Generate numerous ideas that are discussed, considered, rejected and reconsidered

We can see efforts to generate shared meaning through discussion around several topics over the course of the collaboration. B4 began the process of negotiating meaning in their first commit acf15fa to use-cases; discussing first the meaning of the terms and situating their questions within practical experience. The "thinking aloud" was recorded in the knowledge object itself, as shown at Figure A81, with the commit comment pointing to the content and a secondary communication strategy: "First ideas on use case | I wasn't quickly able to do a uml diagram, consider that to come. BUt some questions and ideas to get us started. Will also email around." The next commit 1fcfde6 by B5 did not follow the same method, commenting only "Updated current situation 2019", adding a constructed narrative, diagram and code without asking for either input or feedback.

```
+ Here are my thoughts on the User case for the Automated Course design. I wasn't able to quickly put it into the planttext yet (it has different templates to the video). BTW the video they recommended is great, kinda makes sense now!
+ Also, I wasn't sure who the actors were: the designer? or the instructor & student? But to help the thinking along:
+
+ If a designer was using an automated course design the decisions that would be needed are perhaps something like this (needs to go into planttext but I wasted too much time trying to do this and wanted to circulate). This is based on a designer and what they would 'choose' from an automated courseware system. Is this correct?
+
+ Choose design pattern
+ - Use as is
+ - Adapt it <some steps needed here maybe?>
+
+ Choose format you are exporting to
+
+ Set activity types
+ <<exclude>> video
+ <<exclude>> VR/AR
+ <<exclude>> collaboration
+
+ Set monitoring points (what type of data & when, data analytics)
+ <<exclude>> may need to change activity types
+
+ Teacher: Review monitoring points
+
+ Choose social collaboration points
+
+ Choose assessment types
+ <<exclude>> data analytics
+
+ Questions for the group:
+ is the teacher involved in this process or is it just for designer?
+ It's meant to be high level, so is this too detailed?
+ Do we need to talk about design languages/templates?
+ Can anyone put this into a visual?? I'll have another go later in the week but need to pick up kids now.
+
+ <<exclude>> in a use case  means sometimes do but not always
+
```

Figure A81: Screen shot of initial commit and in-text comments around meaning of terms and practical considerations for use case for automated course design.

When asked to provide references to pedagogical theory at Issue B#44, contributions varied from sharing citations to sharing citations with "takeaways" (comment 1466) relevant to the team's design to also including links and specific points about the relevance to the article to specific features of the team's knowledge objects. Several comments in this issue shown at Table A46 indicated that the team members were able to integrate others' explanations:

Table A46: Excerpts from GitHub interaction data indicating generation of meaning.

Reference	Comment
1465	One of [B2] comments about assessment made me realise that this is a really important part of our pedagogy, and certainly contributes to the WOW factor of the design.

1466	Thank you so much for the contributions above. To echo the Didactics article [B4] put up, from what I read it can indeed be difficult to decide on a particular pedagogy to underpin a particular type of tech use. If an ed tech tool has a particular goal from the outset i.e. to help with inquiry or problem based learning that gives the tool design a pedagogical grounding. [B3] - thank for putting up the embodied learning and PF articles (I am doing a PF study for my dissertation so was very happy to see this here :)). The use of simulations and embodied cognition is highly facilitated by tech use. I am wondering if this could be our WOW factor as they are supported by a significant amount of research.
1488	Key takeaway: The teacher will always need to be involved in the learning design process if the learner is to have positive learning experience. This also highlights [B4] point that teacher input and adaptation is necessary.

General collaborative actions

While it's not clear how the feedback process was determined, there is evidence that agreement from probably two other team members (comment 1326 below) was part of the workflow. Interaction data indicated feedback was sought, as shown in Table A47 below.

Table A47: Excerpts from the GitHub interaction data showing team members asking for feedback.

Reference	Comment
B#10	I have had a go combining Lucy and my Use case diagrams. Please let me know if I have made any major mistakes or if there is anything you would like to change.
B#17	To everyone in the team, let me know if you have comments/suggestions! Thanks!
1324	I tagged you as reviewers to the following pull request:- Added data collection/processing use case I tagged you both since you were faci and KM this week. I hope my changes reflected what we discussed last Wed! Thank you!
B#18	Team, let me know if you have comments and suggestions!
B#23	I am also wondering if we could add some interfaces to the diagram to replace some of the arrows? Let me know what you think..
B#24	Please take a look and see if it makes sense, I was trying to include more data collection and personalisation in the process. Again if it is too much info let me know.
B#28	Please comments as to whether they are specific enough or need to be honed down to more minute levels?
B#49	Feedback/critique is always welcome! :)
1463	I have had a go at changing the most recent use case and sequence diagrams to include design critique. They are in the pull requests please take a look and give feedback :)
B#55	This is my addition of a specific example of how we can incorporate an immersive learning activity. I want to put further narrative with it - eg a real life example of how it would play out and so the stakeholder can visualise it, but I wanted to get feedback first.
B#57	Let me know what you think please :)
B#59	Please let me know what you think, and how I can make it better :)
B#71	Does this make sense?

Although there appears an established document approval process, Table A48 below shows that almost as many interactions simply instruct the other team members to “feel free” to change the knowledge object, or to “scrap it”.

Table A48: Excerpts from GitHub interaction data showing instructions to "feel free" to amend knowledge object drafts.

Reference	Comment
0633644	I've added a description of the use case and a planttext diagram. **Feel free to amend,-** does anyone know how to change it from horizontal display to vertical?
1172	Thanks a lot, [B4]! I'll work on the interaction and component diagrams tonight. Let me know @B2 if you're online so we can chat about it. **Otherwise, just feel free to make commits during your free time.** Thank you!
1326	I tagged @B4 and @B5 as reviewers since they are this week's faci and KM. But for the others, let me know if I reflected what we discussed during the meeting. **Feel free to edit the diagrams and the narratives if I misinterpreted anything.**
1349	Forgot to assign you to this- my draft Design critique work. **Please feel free to amend narrative and image.** **Please feedback/amend in general, but also considering:** any other ways a design critique could be done on scale? is my use case specific enough or do we need more technical details? do we need one to show a design critique process one learning design is being used?
B#40	I have played around with the narrative based on our discussions and to reflect what I have taken away from the diagram. **If it is not the direction we are heading in feel free to scrap it.**
0addaaf	I've updated the readme to reflect work done to week 6/5/19. **Feel free to amend/edit.**
B#46	Hi - I have update the ReadMe file based on: - The discussion in our last meeting on 07.05.19 - Reading the points made in our 'design critique' issue - Peter's request for more WOW factor in our design I realise that the consequence of the changes to ReadMe may result in some changes to a use case. I am happy to update the use case the reflect the changes, once the pull request for the ReadMe file has been approved by the group... or until we discuss any issues needed. Please note that I took the chance and changed Machine Learning to AI to have a consistent use of words in the ReadMe file - but if the group does not feel comfortable using this terminology I am happy to change it back. Also I named the "machine" component of our design LDS - or Learning Design System - just for ease of reference. **Once again if the team would like a different way to refer to it, or anyone would like to propose a different, more creative name - please feel free!**
10e3ee1	Thanks [B2] - yes I this is probably what I was meant to do. **I am happy to do a first go at this tomorrow morning - but if you want to start it before hand please feel free.**
1682	Done- just a couple of sentences. **Pull request done so feel free to edit**

1752	Oh no! I was going to create a new patch for my contribution on _Issues_ but I merged it with @B4 's patch by mistake! I hope it's okay. **Please feel free to amend if needed.** :D

There were several interactions where feedback was both explicitly sought and provided, and others where the team member did not explicitly ask for feedback but tagged other team members with the GitHub review_requested workflow function. One example of a request and responses is excerpted from Issue B#64 at Table A49 below. We can see from these that, in some instances, meaning continued to be negotiated through the feedback process.

Table A49: GitHub interaction data showing responses to requests for feedback on knowledge object drafts.

Reference	Comment
B#64	{review requested} [B1] this sounds great! I have a couple of suggestions to bring some of the statements into alignment with what we have created in the use cases, interactions etc Our vision for the future of learning is driven by our mission to: - Place teachers and learners at the centre of the learning design process. 👍 - Revolutionise how rapid assessments are done through the use of smart learning analytics. - Transform learning experiences to make them tailored, immersive and interactive! ("Fun" can be subjective and is related to selection of content which we haven't gone into so much.) - Make learning tech accessible to all learners of all backgrounds (This refers to economic differences am I right? Could you please clarify how we have targeted this in our work so far?. Is it that we are designing for different platforms etc?) Thanks in advance for the clarification :)
pull request comment 64	Hi [B1] Agree that's a great distillation and brings out what we are aiming for- thank you. RE [B2]'s comments about this point: Make learning tech accessible to all learners of all backgrounds (This refers to economic differences am I right? Could you please clarify how we have targeted this in our work so far?. Is it that we are designing for different platforms etc?) Thanks in advance for the clarification :) I think we're talking about the fact that automating some of the process (AI, VR) etc means it will be more accessible ie machine learning will mean adaptive, more personalised learning is possible? So perhaps something like: Make learning tech tools accessible through automation ?? Perhaps not elegant enough in its phrasing.
1704	Hi @B4 and @B2 ,

	Yes, I had some reservations about adding the fourth point because we never really discussed that in our repo. However, we had some discussions about it last night. So two things: 1. Do we add something about access in our use cases? 2. Do I just delete this part? I think the three points are enough. I am leaning towards deleting it because to be honest, speaking from experience, it's really hard to use high-tech tools like AR/VR or even 2d simulations in developing countries like the Philippines and no amount of learning analytics can erase the fact that our Department of Education can't afford it. Maybe private schools, but not public schools. Let me know what you think!
1706	Hi [B1] I agree with deleting the 4th point. I think it's currently (and in next 5 years) out of reach for most Oz schools also. And it's probably not the time to be adding something brand new to the project that we haven't developed/thought about. We could always include something in our narrative about the aim of improving economic access as it becomes more common and therefore cheaper. Or not! cheers [B4]
1709	Thanks [B4] and thanks [B1] - I did not think about challenges for developing countries, and your right we will not be there in 5 years.
1750	Alright. I'll delete that part and incorporate your edits @B4 and @B2 Thanks for your feedback!

In Issue B#55, B6 adds a narrative and diagram for what is described as an “immersive learning activity”, commenting as shown in Figure A82 below “This is my addition of a specific example of how we can incorporate an immersive learning activity. I want to put further narrative with it - eg a real life example of how it would play out and so the stakeholder can visualise it, but I wanted to get feedback first. Thanks”. They also attempt to commit the document to the master branch despite errors. After feedback from B1 that the diagram does not display, B6 makes several attempts at resolution, and when the diagram displays correctly B4 provides feedback on both the model design and narrative at comment 1566. The author does not respond, and does not incorporate the feedback in their design.

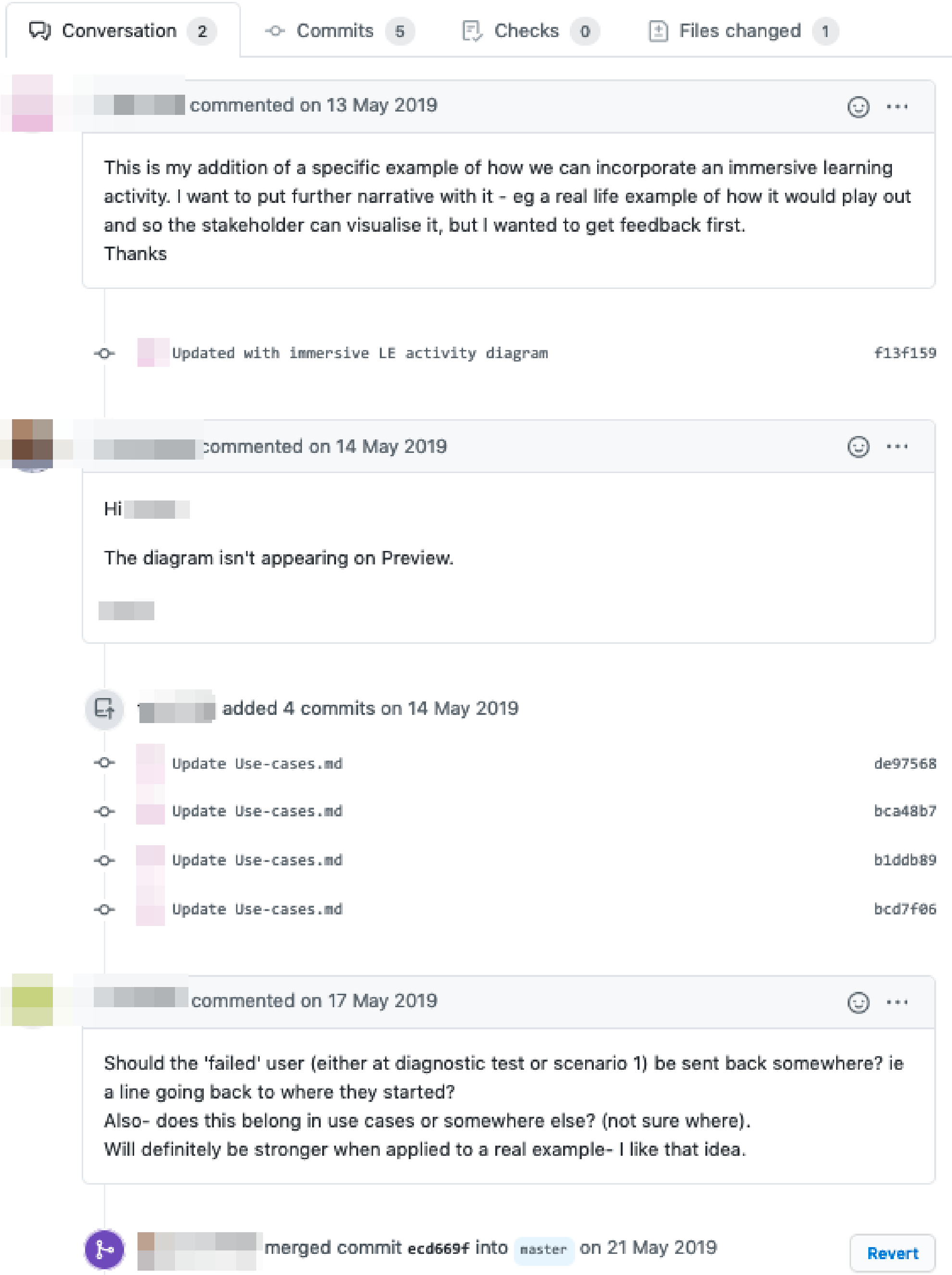


Figure A82: Partial screen shot of comments for Issue B#55 showing feedback on draft use case.

Generally, the approach to knowledge object construction appeared individual, with a task division approach visible early in the project from the first messages shown in Table A50.

Table A50: GitHub messages indicating Team B used elements of a task division approach.

Reference	Comment
B#15	Automated course design: We need to end up with 3 finalised use cases: 1 of current state of play (Michelle has created a draft of this), 1 of ideal (working version done) and 1 of realistic. We have drafts of 2/3 of this (realistic still to come). As discussed in meeting, Michelle, Tahlia & Samadhi to help finalise these, others happy to help if required.
1163	I've updated the meeting notes, readme and contributing docs. I've assigned everyone Issues based on our meeting last night. The aim is to complete this weeks tasks by Friday, due to semester break, if that's possible.

The interaction data excerpted at Table A51 indicates that team members generally worked independently of each other, raising an Issue and Pull Request when they wanted to merge their work to the master branch with sparse elaboration on the underpinning ideas or theoretical issues they encountered during development. At B#20 and B#21 below, we can see that where two team members were working on different aspects the same model, they did not work together, and when B1 asks for help with creating a narrative for their assigned diagrams, the response by B2 is to simply create the narrative and then raise a pull request for it, rather than discuss it with their colleague.

Table A51: Excerpts from GitHub interactions indicating that team members generally worked independently on knowledge objects.

Reference	Comment
B#10	I have had a go combining Lucy and my Use case diagrams. Please let me know if I have made any major mistakes or if there is anything you would like to change.
B#20	I added a sequence diagram here. I think I need help creating a narrative for it. Let me know if you're up for it!
B#21	Similar to the sequence diagram, I also added a component diagram here but I think I need your help in creating a narrative. Thank you!
B#28	These are my first drafts of the collaboration use cases. I've created a branch off the master for these.
B#38	Added Data collection/processing use case
B#49	Have a look at the use case I have put in with its narrative/justification. I have also jiggled a few things around such as renaming the Instructional Designer to Learning Designer, and put in that the Unique Learning Environment selects the Online Content rather than vice versa.
B#55	This is my addition of a specific example of how we can incorporate an immersive learning activity. I want to put further narrative with it - eg a real life example of how it would play out and so the stakeholder can visualise it, but I wanted to get feedback first. Thanks
B#59	I have had a go editing the interactions document. The main change I have made is to rename Tech Device into Tech Tool, I have done this so we can include ed. tech. software as part of the sequences not just physical devices. I have also tried to clarify the changes between the 3 scenarios, these being current, near future and ideal. I can have another go at it later on.
B#75	Hi everyone, I made a minor (or major?) change here by changing the title:<title removed>

There are, however, two notable exceptions. One detailed exchange Team B had was in relation to a major edit one team member had made to the team's README, intended to simply reflect the current repo 'state of play', but which this team had adapted to reflect their design rationale. Another team member used in-text review comments (the only use of this feature across the teams) to make two suggestions, and in their third comment asked what the other team member had meant by "style of learning". Table A52 shows the sequence of comments that follows on this topic, across a range of GitHub actions, showing that team members draw on both personal experience and theory in their discussion around the validity of this concept, in the end deciding to avoid the term and the original author changes it to "current level of knowledge specific to the subject to be learnt, as well as relevant learning goals and interests" at commit f21f6c6. I have used a series of partial screen shots in the Table as the comments are not contiguous and to capture some contextual information.

Table A52: Partial screen shots of GitHub interaction data discussing the inclusion of the term 'learning styles' in the team's README.

Reference	Comment
commit 39ebea4 with in-text review comments (unnumbered)	+ **Rapid Understanding of the Student's Strengths, Capability and Needs** + + The teacher will set parameters within the LDS's Artificial Intelligence (AI) assessment tool functions to gather information on the learner's style of learning, current level of knowledge specific to the subject to be learnt, as well as relevant learning goals and interests. This will not be done in the traditional "questions & answer" type assessment. Instead as soon as the student begins interacting with the system, it will start to gather data about the learner in a naturalistic way. The more students interact with the system, the more data becomes available to feed back into the system and help create future personalised learning environments. [redacted] on 11 May 2019 Whn we talk about "style of learning"? What do we mean here? [redacted] on 11 May 2019 Author There are lots of models for styles of learning - so your right that we should define it. The primary modes that I think of are Visual, Kinesthetic, Auditory, Inductive/Deductive, Active learners, Reflective , Sequential (i.e. list and steps), Global learners (more abstract, how everything fits together).
PR comment 168, 169	In relation to authentic Vs naturalistic: after some research I would like to propose we use both terms, as they are both valid (please see definitions that I found below). Also after the research I realised this is an important part of our pedagogy - so will include that there as well. Meaning of **naturalistic assessment** is that *"in a way that is both unobtrusive and ecologically valid"* (From The Oxford Handbook of Psychological Situations, 2018 -https://www.oxfordhandbooks.com/view/10.1093/oxfordhb/9780190263348.001.0001/oxfordhb-9780190263348-e-14) Meaning of **authentic assessment** - *"focuses on students using and applying knowledge and skills in real-life settings"* (UNSW, 2018 https://teaching.unsw.edu.au/authentic-assessment) [redacted] on 11 May 2019 Super, thanks for the clarification [redacted] :) I heartily agree we should include naturalistic and authentic assessment. And a very good point about the learners individual goal setting - a key factor for learner engagement, we should definitely include that also. I am hesitant to include references to learning styles into our rationale however, as they have come under alot of scrutiny recently. There has been a growing number of research papers into the rejection of learning styles based instruction (particularly the visual/auditory/kinaethetic). They sight that there is little theoretical underpinning of learning styles theory and little peer reviewed research into its efficacy. Here is a recent paper on the subject: • An, D., & Carr, M. (2017). Learning styles theory fails to explain learning and achievement: Recommendations for alternative approaches. Personality and Individual Differences, 116, 410–416. https://doi.org/10.1016/j.paid.2017.04.050 This particular paper mentions looking into supporting self regulation, fluency and abstraction to account for learner differences. I would love to hear what others think though? What have you all heard about learning styles? [redacted] on 12 May 2019 I remember hearing one of the lecturers say learning styles had not held up to academic scrutiny/no research to uphold it. They mentioned that everyone learns in different ways at different times and for different things, but that there is no academic research to back up people having a preferred learning style and the need to base learning around this style. So- i would say let's avoid learning style and talk about tailoring it to their existing knowledge base /or expertise and taking into account the learning goals.
PR comment 174	[redacted] on 13 May 2019 • edited I agree to omit "learning styles" because as mentioned earlier, it's highly contested in the literature I've gone through so far.
PR comment 175	[redacted] on 13 May 2019 Author Really great feedback everyone - thank you. I feel like our project has really developed, and we are getting to the heart of some great ideas. I think we should include all the points raised, and I am more than happy to delete the learning styles. I know that I definitely have a learning style - so maybe that is why I adhere to that idea. But I had not seen the research that disputed the concept of learning styles so thank you for sharing that. I planned on merging everyone's feedback into the Read Me file tonight, but there is quite a bit of feedback to merge now and feel like I will not do it justice tonight - so I will do this in the morning . My writing accuracy definitely drops in the evening! :)

Regulative dimension of actions

Projective

While it was not clear from the GitHub data whether Team B had a deliberately agreed collaborative strategy, we can see there was an agreed workflow that was renegotiated during the project. Figure A83 illustrates this through the conversation that resulted from the instructor task to reflect on whether the actual workflow was represented accurately by the team's processes diagram.

Figure A83: Partial screen shot of Issue B#45 showing evidence of agreed team processes.

Deliberate actions toward joint knowledge object development are also visible in these excerpts from GitHub issues and comments, shown in Table A53 below. There is also a mention at B#11 of “Research on LDEs”, in a list that includes “Come up with use cases for different platforms” and “Create diagrams”, with all boxes checked as if they are complete. There are no further associated details.

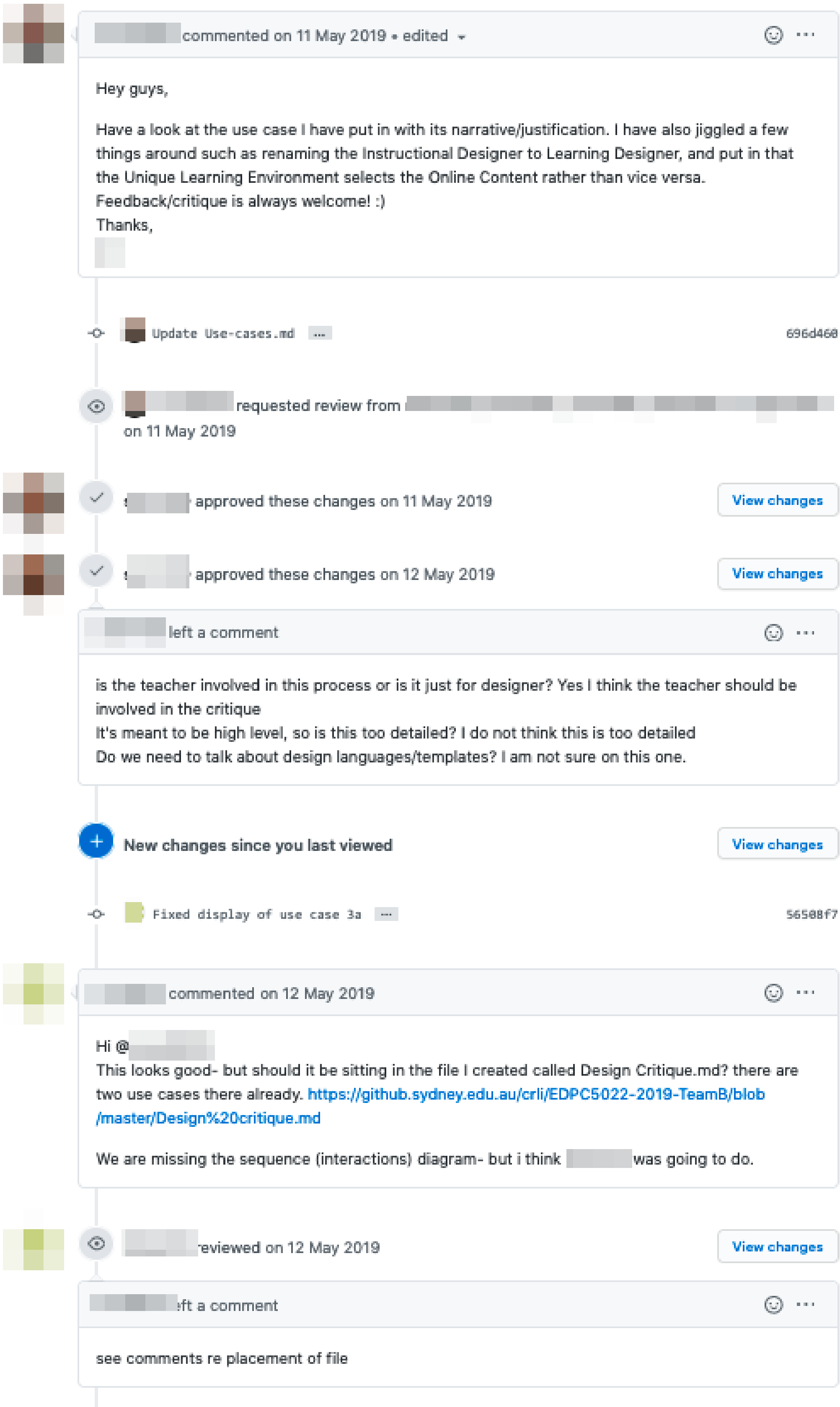
Table A53: Excerpts from the GitHub interaction data illustrating an agreed workflow process.

Reference	Comment
0982	I don't seem to be able to add milestones or assign to the rest of my group.
B#5	- [x] Meet and discuss workflow draft - [x] Create UML diagram to illustrate workflow
B#7	I think it can go into the master branch but wasn't sure.
B#8	I'm happy for this to be merged in.
B#33	happy for you to merge changes in
B#47	Happy to go ahead and merge this
1477	this looks good happy to merge into master
B#60	I'm happy to merge this in- I fixed some typos but otherwise it gives a good sense of where we're at this week.
1654	Thanks @B4 and @B2 . I won't merge this yet until everyone has approved. :D

Regulative

Monitor object development and quality

The interaction data at issue B#49 in Figure A84, while rather long, illustrates confusion around the task, the knowledge objects and the process just two weeks before the task was finalised. We have also seen that there are interactions where team members ask others to “check” their work at B#23, to let them know if they have “made any major mistakes” at B#10, if they are “wrong” at comment 1471, or if things are “not resolved” at B#72.



-figure continued on following page

Figure A84: Partial screen shot from Issue B#49 showing confusion around task, knowledge objects and process in Week 10 [remainder of code and diagram removed].

Collaborative characteristics of GitHub Actions/Interactions: Team C

Epistemic dimension of actions

Creating awareness

Table A54 shows that Team C discussed their goals in their asynchronous interactions as well as in meetings, returning to key points from the task to re-evaluate their ideas.

Table A54: Excerpt from GitHub data showing Team C's approach to goal clarification and need identification.

Reference	Comment
1216	Ok, what I understand is that our use case is too broad for the scope we are supposed to aim at this week. So, we might need to break it down. So Peter is saying that we have "**to think of a system that takes a learning design as input, and that transforms the design description into a "course" that students "follow" (or, more generally, a "learning environment" that students interact with)".** So let's think about the actors first: - One actor has to be a **learning designer** that creates the design - Another actor has to be **something/someone that generates the course based on that design** - Finally, the end-user aka **the learner** - Now, Peter also asks us to consider an **administrator**, someone who approves the learning design before it is deployed. So that would be our fourth actor I guess So what's next? I think we need a meeting lol
1232	As to whether we stick to one model or two is a bit obscure in the assignment: "Envisioning the future involves brainstorming ideas for two future (think 2025) scenarios, an "achievable" and an "ideal" one. Designing the future involves modeling key parts of one or both of the future scenarios. " So we're supposed to think of two but model just one (or two)? If we only model one, then how does the other model get captured for the assignment?
1234	I agree with you Made. I think the current model is only one model and we leave it like that. And then we should be working on changing and updating the AI model as we progress in the project. (Shouldn't we probably be reading the literature to get more ideas?)
1239	I think on tuesday we just have to confirm with Peter about how many scenarios we should be working with (achievable and ideal). I have a feeling these next tasks will be based more on a future scenario and we may have just jumped the gun. As soon as we have an answer on that we can move forward and quickly create the models needed.
1284	I think that we might also need to have a look at the bigger picture and where all our various models fit in (this will probably naturally come about when we look into Dominique's interaction model when we do the critique). While there is overlap between the models (which I see as a good thing), I'm worried that when you step back some of the models are contradicting each other. I think it may be good to sort of lay them all out, step back and look at the big picture flow / story and how they all fit into our overarching scenario.

Alleviating lack of knowledge

While as a group Team C most often searched for solutions by asking other team members or by individually searching elsewhere, they were good at explaining what they found to each other. Although, when knowledge shared was not quite accurate like in commit 7cef195 "Made diagram visible by changing inverted comas", where the backticks were removed and it was not until several commits later at commit 4d69b65 that it worked, there wasn't a corresponding comment in the successful commit. Or, where commit b280145, accurately uses the commit comment "Updated arrows on Use Scenarios", the following commit bb2a654, "Updated Arrows to Use Scenarios", might conceptually be part of the same phased change to the document, but is actually a minor change to the formatting of a list within the narrative of a use case. As commit comments are made when the edit is made to the file, the editor might not yet be certain that their change has had the effect they are describing (although a preview of changes is available) and so these comments might be considered less reliable than those at Table A55, which are detailed and generally accurate.

Table A55: Examples of sharing insights with other team members.

Reference	Comment
C#14	Added link on how to make folder in Github
1139	Hi [C6], your model is just plain text and it's in the branch "automated course use case 2", so you won't find it in the use case master branch, for some reason it hasn't merged. It says that the pull request is "closed" so I don't know how to reopen it and pull it to the master branch. But the text isn't gone, it's just in a different branch. Take a look<link removed>
1141	Ok, so it's looks like I hit the wrong button the first time - oops! sorry! BUT, I was able to re-open it and merge it this time.
1198	It's like this ![name of the diagram}(URL) if you wanna include and image, and if you wanna include a link, say a plantuml URL then it's the same but without the ! mark. Whatever you write between the [ ] will be the name of the link, so the URL won't show, just what you write in [ ] will show same as a hyperlink on PDF. Hope this is useful.
1408	@C5 for us to see the actual diagram on the repo, you've to paste your plantuml URL generated from PlantText as an image not as a link. So, the formula for pasting images on the repo is this: --> Type an exclamation mark ! then open [type the name of the component diagram here](here you paste the URL).
1656	Nice model! I would eliminate SCORM and only leave Tin Can since the latter is already an upgrade of SCORM.
1666	I noticed that the conflict was because you changed the title of the component diagram to "Component Diagram #2" and it was on the same line as the title of the old component "Components - Component Diagram". So, hopefully, now you can merge it. Can you try? and please check that your intended change is actually there. (I watched a tutorial on youtube on how to resolve conflicts) <link removed>
1835	have added a screenshot of the code here as even the issues section read git code and converts it to the more presentable font you see when you commit things. Remember to add the hyperlink of the exact spot of the model on the page by hovering your cursor to the left of the model's heading until you see a hyperlink icon.
1855	it's for each of our diagrams we have created to link between the specific other diagrams related to it- so the components diagram, with the specific interactions diagram, with the specific use case for each of the components. For example:<link removed> So the part where it says: The Learning Analytics Platform Component Diagram aligns with: The Learning Analytics Platform Interactions Diagram found here Hope that makes sense.

Table A56 below shows the conversation while Team C is waiting for a reply from the instructors about the inclusion of AI in their model, showing other team members stepping in to the conversation, with one suggesting a conceptual explanation along with an empathetic expression of shared lack of understanding. A third team member steps in to confirm the conceptual explanation and to disambiguate the type of model from other types in which AI might feature in a role, and we can see that it is the same team member who has been using reference materials to develop their modelling skills at comment 1099 above, and who suggests “(Shouldn't we probably be reading the literature to get more ideas?)” at 1234.

Table A56: Excerpts from Issue C#22 where team members discuss the role of actors in use case models both generally and specifically.

Reference	Comment
1187	Hi everyone, could we all have a look at the two models in Use Cases.md to see if we are happy to proceed with these? This is especially important if we are moving forward to Interactions models. Personally, I like the reversal of the 'CoachU' idea to the beginning, using students' questions and discussions. The only thing that poses a problem I find is in the case of students who have never studied a course under that analytics system before. Do we then use their prior marks elsewhere and a survey of their learning aims/intended direction? @C3 you had a great Components model before - did you want to adapt this for the Wk8 Milestone?
1189	Actually, I was thinking more broadly that the analytics was the learning part of the AI whereby the machine could learn and make assumptions on future students based on all past students - not necessarily any particular students. Also, I was thinking that we should add the Coach U at the end of the model so that after the first interaction with the course, the AI then also provides additional learning which also leads to more analytics for the machine to learn from. But, (I messaged you all in the other chat in the pull request), we might have to re-think this whole model now in light of what Peter's comments that EB sent around saying that AI can't be an actor in a Use Case.
1192	I kind of agree re: having coachU at the end but also don't mind if you want to change it. @C1 I don't really understand exactly what they mean by AI can't be an actor. Perhaps it is more a comment on it not being an actor who interacts with the system on the same level a user does (i.e. doesn't have a role in the same way) but can be incorporated into the UML in other ways
1196	AI can't be an actor in Use case diagrams because they represent the interactions of users with the system and AI isn't a user. Also, appreciate the uplifting comment on my component diagram but that's not a component diagram based on the info we got from EB and Peter last class so I'll work out one new CD and do it in my branch then do a pull request. Use cases are for: - Concrete interactions - User roles--> not the tech - They describe an operation on an object in the interface - High-level requirements

1203	I'm getting confused because what we're talking about is essentially the Use case model I had before the change after our meeting. The model had the AI system, with three users: learning designer, teacher and learner. The AI was not a 'user' and CoachU functioned throughout but also at the end. I think we're possibly over complicating things by trying to rearrange things then. Do we want to go back to it?
1204	What I would suggest is perhaps to change the name of the 'AI' outside of the system rectangle to Course System Designer. I don't think in 5 years time it is possible to forego a system designer or a teacher/course designer. I'll try and make a few tweaks with that.
1205	I think the difference between your model and my model what that you had a learning designer at the beginning initiating the whole sequence where I tried to make AI do all the work from the beginning and initiate the sequence where humans only approve it (the designer) and use it (the learner). I'm still waiting to hear back from Peter for clarification. If we can't have the AI be a user, then I'm really not sure how to model this scenario unless we call the AI "machine designer" or "system designer" and the human "human designer", but it's only in the title then. I think in 5 years it's very possible that this will be happening. It is already happening in the US (I read a case study last year on a uni using it) - IBM Watson has an arm dedicated to it. And check this out:<link removed> But, if we have to take out the machine altogether from the model then the model will really only be: - human designer approves or tweaks course that AI designed - Learner uses new course I think a simplified model like that will then miss out on all the actual process components (unless these are supposed to go into another model and captured there.
1209	I get what you're saying more now @C1 and I think my thinking is along the lines of someone (a human) has to actually initiate something somewhere at the beginning to kick off the entire process which cannot be an AI. Here is my thinking out aloud: - If we get rid of the system designer altogether, who actually maintains the system itself and provides the tech support? - Are we using a cloud base system (which was in the initial model) where online users add their own learning models, pedagogy, activities, resources, trends? - Can the learner initiate the sequence of design and the teacher approves/monitors? - How does the AI initiate anything if it knows nothing about the learner or the user needs? In this way, could we have: a) The learner initiate the design by inputting their learning goal and past results from other courses if applicable b) The AI system (inside the rectangle) would process that and any other information from the analytics engine to design the course c) The teacher approves the course (or can go back to any stage in the design process to modify)

	d) The learner engages with the learning environment (giving the analytics engine more data) e) xapi tracks and monitors to then self-design additional course suggestions (CoachU - can be another name) (optional) f) System designer maintains the cloud depository and maintains the overall support system Then, the Use Case model will have: System Designer, Teacher and Learner. Otherwise, we will simply have the Teacher and the Learner.
1212	Hi Everyone: I heard back from Peter - here is his email. In light of what he says (not sure I fully understand all of it), but it sounds like it will require a lot more work and several more models, so my suggestion is that we ditch this model / idea and go with the first two models we had – [C2] and [C4]'s (I think it was [C4]'s? Or [C6]'s? sorry - forgot). Here is his email below: <text removed>.
1216	Ok, what I understand is that our use case is too broad for the scope we are supposed to aim at this week. So, we might need to break it down. So Peter is saying that we have "**to think of a system that takes a learning design as input, and that transforms the design description into a “course” that students “follow” (or, more generally, a “learning environment” that students interact with)".** So let's think about the actors first: - One actor has to be a **learning designer** that creates the design - Another actor has to be **something/someone that generates the course based on that design** - Finally, the end-user aka **the learner** - Now, Peter also asks us to consider an **administrator**, someone who approves the learning design before it is deployed. So that would be our fourth actor I guess So what's next? I think we need a meeting lol
1217	@C3 Yes, I agree with what you said above (I think you understood it better than me and definitely explained it better!). But, I think what you are describing above is in fact [C2]’S model that we already have (except for maybe the approver). Except, have we now lost [C2]'s model as our future model in all the merge's? My suggestion would be that we ditch mine and go back to [C2]'s as it seems to meet the brief better.

Creating shared understanding

As well as engaging in discussions around the parameters of the project task (C#17, C#31), Team C spent time in GitHub generating and negotiating meaning by asking questions about the features and functions of their model designs, and the way in which they connected with each logically. Early on in the collaboration they made a decision that the models would need to make sense as a coherent whole, and even when that meant extra work to re-align diagrams and code in line with new realisations, Table A57 shows comments over the course of the project indicating that they continued to engage in rigorous discussion to ensure they were creating shared meaning.

Table A57: Excerpts from GitHub illustrating Team C's approach to generating and negotiating meaning.

Reference	Comment
C#29	This is awesome [C3]! Nice work. Just to wrap my head around it a bit more - how would you define the "services layer" - I am asking because I would like to know why needs and constraints can be listed under services.
1369	Hi @C3 component model #2 looks good. However, is it an add-on to #1 or in replacement of?
1374	Hi @C6 this to me represents the core components of the Personalisation Engine. I'd imagine the Boundaries Tool is the User Interface that the user inputs the criterias into?
1380	Yes that was what I was imagining. Would a diagram like this go into more detail on the steps taken by the user when first engaging with the PE. For example 1. set pedagogy, 2 set learning objectives, 3. set boundaries. Or is that reserved for an interaction diagram?
1397	But, having said that, what you put here makes sense to me, but do we need to have the student also feeding in to the analytics? (I guess the questions they ask, their progression and performance, etc.)?
1498	Just one question about the Learning Analytics Platform Characteristics. Particularly about his part: ""Course designer will only engage with the Personalisation Engine not the Learning Analytics Platform."" Would the personalisation engine also have the learning dashboard? I'm wondering where the teachers can access data to monitor students' progress.
C#54	A few comments/questions regarding my updated model and [C2]'s use scenario that we are now all adapting to. [C2]'s narrative says "The System designer will manage and add to the cloud depository and both Personalisation and Learning analytics engines. Also offers technical support and administrate." However, on the model SD to PA or SD to LAP is not represented. Can you let me know if it should be so I can also add this. [C2]'s narrative says "If using the Learning analytics engine, the Course designer will activate it and it will use either the Cloud depository/web search engine or both to then generate a suggested Learning environment." On the model LAP doesn't go to web so let me know if it should and I will add this to my diagram as well. [C2]'s narrative says "The Personalisation engine will feed the information through the cloud depository and generate a Learning environment appropriate to the boundaries set." I am not sure about this one. Isn't the PE the UI that the CD sees? Wouldn't the PE pull data from the depository to show the CD and then the PE would generate the learning environment? This would then mean that [C2]'s model needs an arrow to learning environment. Understood that if you guys disagree I will have to change my model. I think we have kind of gone bit backwards in terms of our approach with the Learning analytics platform. It was my initial understanding that xAPI was monitoring user behaviour, processing that info into LAP which could then generate additional resources without any additional huam interaction (futuristic/or maybe even achievable now!). Now we have it all being relayed back to the CD and they generate the additional resources from the PE. I would think that we would have the tech to have this be automated rather

	than having another human being involved. Let me know what you think and I will adjust my model accordingly.
1476	My understanding was that the System Designer was really just IT support? Maybe the title needs to be changed as Designer is a bit misleading. I think the idea was that they are only adding IT support, not necessarily anything else to the PE and analytics. My understanding was that the Learning Analytics just feeds analytics data into the PE. When the Course Designer wants to set up a new course, they put the info in (eg. dates, timelines, student info) into the PE, the PE looks for activities and resources from both the depository and the web, then comes up with a course design suggestion. The Course Designer then approves that design and then the PE sets it up in the Learning Environment. I agree with you that in the future it would be good to take out the humans and have the PE (AI) do everything (which was what my original AI futuristic model did). But when we got the feedback from Peter that he still thinks humans need to be involved we went back to having a human give the tick of approval. My understanding from what we discussed on Tuesday is that the Personalisation Engine is the user interface for the Course Designer, but it is also the real AI (brains) component. The Learning analytics feeds the data into the PE and the xAPI stores various learner data, but it's the PE that uses the information from all the various components to then make suggestions and create the learning environment.
1585	This is good!! Thanks for doing this. Is it appropriate for us to somehow represent how the data is being used here? i.e. Is AI able to adapt the course based on the users engagement with different devices. Maybe this is going a bit far but my mind is going to collecting data on how users engage with content, e.g. someone who uses their phone a lot may have a shorter attention space and want information delivered to them in short videos or short articles.
1590	This is awesome but remind me why xapi also feeds to cloud repository?
1610	Noup, xAPI only feeds into the LAP and the LAP into the PE. So, the answer is it does feed into the Cloud Repository but not directly, only through the LAP (this aligns with [C5]'s latest narrative for LAP added in her component diagram).
1800	Hiya - yeah that model looks good for the student to be an initiator. I wonder though if it would be cool to also have an arrow going from the learning analytics back to the PE so that it is an idea that while the student is taking the first course, the data is being collected and analysed and then the analysis is feed back into the PE for further customisation for the next course or for additional activities? Just a thought...
1844	spanner in the works but does it need all the extra detail or should it just focus on the PE? E.g at no point does instructor or learner interact with it so may not be necessary. It starts to look like a repeat of other diagrams if it incorporates other elements. Just my two cents!
1846	Understand what you are saying @C64177, rationale behind it was because the data from that back half is fed back to the PE for further ammendments / future recommendations I felt it was still a part of the process. I can easily remove it though if we think it isn't needed.

General collaborative actions

While the team meeting notes will be analysed separately for the purposes of triangulating the GitHub data, we can tell from the interactions at Table A58 that the development of the knowledge objects was discussed during group meetings, and from commit comment 9156a8f "Updated Parent Scenarios Post Meeting" that changes were made in consequence.

Table A58: References in comments to discussion of knowledge objects in group meetings.

Reference	Comment
1049	Anyway, I'm looking forward to getting stuck into this tonight in our meeting. :-)
1106	Will discuss this further tonight but I liked the one used by EB for her research.
1234	I think we need a meeting to define the solution for the use case drama!
1313	I hope that makes more sense! Maybe something to discuss at our next meeting.
1398	Let's discuss tonight. :-)
1404	Maybe we can discuss tonight and I can always resolve it and merge it tonight if that's what everyone wants.
1405	Yes, I think we should discuss this tonight! No worries.
1656	The rest of the components we can discuss tonight in our meeting!
6813e50	Updated description to reflect this additional interaction as discussed at the last meeting.

Just a week before the task was due for submission, the team realised that the 'CoachU' code they had worked with early in the project was a good foundation for the new model, and worked out how to build on it to design the necessary integrations with other systems. This was not the first time 'CoachU' was the topic of a thread where ideas were reconsidered. In the Week 8 conversations around AI, a team member had contacted the instructor to clarify whether their diagram was consistent with the task brief, and the team were discussing how to proceed with work over the upcoming Easter break in C#22. During the conversation the team debates whether a prior version of the model was in fact a better fit for the brief than the current version, and determine which elements would need to be present in order to be feasible, "thinking out loud", pointing to a youtube video, and posing questions and assumptions. When they hear back from the instructor, C1 posts the message to the team commenting at 1212 "it sounds like it will require a lot more work and several more models" (despite the instructor saying in the message "There is no need for you to work further on this as you already did a lot of work."). C3 then summarises the instructor's point and breaks down the system *actors* which match the assumptions worked out in the conversation above, and after others agree on the actors, they conclude that the previous model is what they need and together use a range of strategies to locate the previous version in the GitHub history.

Idea generation began early in the project with comments showing input on suggested models was provided at both abstract and concrete levels as part of an agreed workflow process and also a genuine elicitation of individual ideas toward mental model alignment and shared model co-construction. The examples at Table A59 are from Week 7, the second week of the project, in which the team are in the first stages of discussing a 'futuristic' learning scenario, and the point at which the CoachU scenario, which would be reconsidered in Week 12, was first ideated.

Table A59: Examples of a thread of individual ideas contributing to intra-team brainstorming in Week 7.

Reference	Comment
1049	Wow this looks amazing! I'm impressed with your PlantText skills! I wonder if the content could actually go after the use of Genie - for example, I wonder if in a future world you could just say "We need a course that does X" and then the program will look at the existing materials, and will identify a time duration to complete it and will also create the assessments.
1087	I think what [C1] said is something we should be considering. In that future automation programs could utilise AI in generating content, surpassing the need for a content designer (perhaps it would be someone's role to refine AI course content, or adapt it to a specific brand).
1106	I think this is a good start and definitely fits in with the brief. Having the pre-set depository is an important middle object. I think a surveying system where the user inserts the needs is also necessary to establish boundaries for the depository to generate the appropriate course and system to use. Will discuss this further tonight but I liked the one used by EB for her research.
C#15	Following on from the discussion, I had another idea about future learning environments which I added to the model labelled CoachU - basically AI tracks the student's learning in the environments and then self-generates further courses for the student to help them reach the learning goal (whether it's the end of the semester, course or degree). I thought this would fit in with the whole adaptive system idea we had. This is already done in schools like NAPLAN testing where it uses a tailored test design, that automatically adapts to a student's test performance and asks questions that match the student's achievement.

In the early stages of the project the team expressed confusion around the task and the environment, seeking clarification from the instructor about model elements and GitHub use. Issue C#31 reflects their efforts to reflect as a group on how their ideas so far align with their sense-making around the task. The conversation is too long to reproduce here in full, but an excerpt from one team member is at Figure A85, showing parts of a discussion around the models which had been developed so far, and the meaning of specific elements within them, suggesting further elaboration in the context of recent information from the instructor.

[redacted] commented on 28 Apr 2019

Hi everyone,
Sorry I've been a bit MIA as I was struct down with a chest infection which developed into pneumonia. Still recovering at the moment. I'll try and address a few things:

1. Use case models - agreed that the 'achievable' one (Use case 3) can stay as is.
   In terms of the AI system, I suggested 2 Use cases in a pull request and tagged everyone, then it got merged and I'm not sure by who or when so hence we have Use cases 1, 2 and 3.

For your reference, the discussions seem to centre on two models:

a) Original version that everyone has been looking for: https://www.plantuml.com/plantuml

b) The updated one (Use Case 2).
https://www.plantuml.com/plantuml/img/hLCxJyD03DxlLtXi1s3FWAXeXqeTAdLWhDoS2POINtHsAYh4VyTDU5LA2qXCbtDyt-

Reading [redacted]'s email, he indicated that different types of arrows meant different things and so I attempted to update the meaning of the arrows. The dotted lines means that the user has options of using one or the other whereas full lines means that it is a necessary flow. The CoachU was changed to xAPI as that is actually the engine. Calling it CoachU can be too vague. Also, I specified the possibility of the xAPI doing an automated web search.

I can explain this more on Tuesday's meeting. I'd suggest we keep either Use case 1 OR 2, and Use Case 3.

Based on [redacted]s email, he did suggest that we have smaller use case models for the parts in the system that requires a specific breakdown of where the users interact. I would suggest that we have a smaller model to extrapolate the Course/Environments Depository and the Learning Analytics Platform to show how the users interact with those specific parts of the system.

Contributing/Pull Requests
We could tag the whole team in each pull request. Last time we discussed changing the sequence of pull requests, it was left inconclusive as we also realised that we needed pull requests to be merged before Tuesday as peter goes through each group's work. If we leave it to decide on Tuesday's meeting, it will be too late and we won;t actually have anything to show as we won't have decided on anything. As a suggestion, we could have our meeting on Sundays so that we can finalise pull requests and the KM/F can generate any meeting items for Tuesday.

Figure A85: Comment 1240 from C#31 illustrating team discussion around both epistemic (modelling elements and notation) and regulative (approval process) aspects of the task. URLs have been truncated to save space.

The conversation took place over nine days, with outstanding issues taken to a team meeting for further discussion, and the issue only closed after agreement from three team members, as shown in Figure A86.

[redacted] commented on 3 May 2019

I think we can close this issue now, or we're still keeping it to read through the discussions?

[redacted] commented on 5 May 2019

Yes, we could close this issue. Do we have approval from KM?

[redacted] commented on 5 May 2019

Yes, I'll close it.

Figure A86: Partial screen shot of Issue C#31, where the team decides the conversation can be closed.

While the feedback process was embedded in the team workflow, the request was also often explicitly stated in an issue comment as well, as shown at Table A60.

Table A60: Excerpts from interaction data illustrating explicit requests for feedback.

Reference	Comment
C#28	Hi guys! my attempt at creating interaction diagram from use case #1 I don't know if we have to add another entity between the depository and the learning environment - I guess it could be 'AI' What do you think?
C#35	Please review Use cases 1 and 2 to see if they are appropriate. Critique and propose any changes.
C#39	My biggest change was between the personalisation engine (PE) and cloud database (CD). I thought that the course designer would be interacting with the PE so the CD would push the data back to the PE so that the course designer could see what has been collected and make adjustments if needs be. What do you think?
C#40	I am not sure if I am on the right track so wanted to put it out to everyone. Any suggestions on how I can improve this as it seems so simple. Haven't added the text of edited text of interaction scenario #1
C#44	Hi guys Do we think this is too simple and still too broad? Let me know?
C#46	Hi all, Still second guessing myself about this so really would appreciate feedback. [C5]
C#58	I updated the AI Adaptive LD System Interactions Diagram to match the use scenario and also made a few edits to the rest of the page to make it consistent. I also added the links to other diagram that it may connect to. questions Should there be an arrow to course designer to cloud depository to represent that the CD can also add data or is that redundant as the CD may have the function to deposit data within the PE itself? Regarding how users deposit to the CCD, is this a separate interface?
C#59	Hi guys I edited my interactions model ad added links to other models it may connect to. What do you think of this format? Found here: <link removed>
C#62	I am not sure if I went totally crazy here but what do you think of the repository and learning analytics integrations within the PE?? Also does anyone have any recommendations on layout? I struggled to make this visually appealing and found it hard to code exactly where I wanted the sections to sit.
C#86	Thought I would put this up for discussion. I ended up doing a use case without AI as an actor because it didn't need to be. What if the entire LE has smart functionality, as stored user data and made decisions within the platform without an other actors interfering? What if a CD and COP only added to the repository? So was able to elevate the experience by providing more resources for AI to read from? I think this is

	a good start but could be expanded upon. Especially if [C4] has her own ideas coming out of the research she has done. Let me know of your thoughts.

It is clear from the GitHub interaction data that Team C incorporated the feedback received from other team members iteratively during the development of their knowledge objects throughout the course of the project. We can see from the section on agreed feedback processes above that it was a deliberate decision, and from comment 1284 point 1 that the team considered the process important enough to want a persistent record of the conversations: "I know in our meeting we said we were going to do critiques in the pull requests for all our models, but I think the comments in pull requests get deleted once you merge the request, so while I think it's a good idea to have the conversation in the pull request before we merge it, we may want a summary of the conversation recorded somewhere so we can refer back to it.". We can also see from the interactions at Table A61 below the efforts of team members to model the feedback ideas they had in order to better communicate their meaning.

Table A61: Excerpts from interaction data illustrating feedback as object sections were developed and efforts by team members to model the feedback ideas they were expressing.

Reference	Comment
1285	In the sequence diagram that I did today (see pull request), I have in there that once the Personalisation Engine retrieves information from the Depository and the Web that meets the criteria that the course designer specified (eg. subjects, timeframes), then the Course Designer needs to approve it, then the Engine sets up the course in the Learning Environment. I wonder if we can slot in Design Critique in there somewhere... Maybe one of the following options: 1. Course Designer approves the resources and the activities, the Engine sets up the course in the Learning Environment, but before it goes "live", the Course Designer, Teachers, other experts / designers, and a pilot group of students runs a design critique and then it's not until all components of the design are approved that it goes live in the learning environment 2. The Course Designer approves the resources and the activities, does an initial design which then goes through a design critique (same participants as above), then once design is approved, it is entered into the Personalisation Engine which then sets up the course in the Learning Environment. My only thought with this option is that it then has the person doing the design as opposed to the AI which sort of takes away the "ideal" scenario. Actually in a really futuristic world, I wonder if you could remove the humans and have the AI do the design critique of its own designs based on learnings from previous critiques..!? Thoughts? I'm happy to add something like this to the sequence model to see what it looks like.
1372	Great sequence diagram, makes total sense to me! Thanks for putting the link, definitely it was easier to understand the model.

	My only suggestion would be for the Course Designer --> Personalisation Engine. I think that we could add an arrow with the action "enter students or learners details" as this variable can also impact the type of course that the "personalisation engine" will set up.
1375	I like option 1. Once the "personalisation engine" generates a course's prototype, the experts run a design critique and then, the system takes this feedback to make adjustments. So finally, the course goes "live" in the learning environment. Here is my attempt: <link removed> Is this regard and taking into account Peter's questions, I think that we also need to consider: How do we engage experts to contribute to the design critique? (motivational aspect) How do we capture expert's feedback in a way that the "personalisation engine" o the intelligent system can read and interpretate the information? Is there any posibility to replace "expert's judgement" in the design critique stage with an AI system? Considering that the AI system counts with heuristics to emulate expert's evaluation criteria and also it has been collecting data and learning through the analytics platform.
1378	So in reading the articles here and others online about Design critique Processes, there are a lot of variances so I've tried to sum them up here into a possible structure for a use scenario/use case. Users: 1. Presenter (Course designer who has the most in depth and context specific knowledge of the model) 2. Facilitator (System Designer who establishes the key goals to assess the design against) 3. Note-taker (Instructor) 4. Other critiquers (includes developers, other product managers, stakeholders, pilot students, learning experts, etc) Use case could involve the broader categories of: a) Facilitate: sets agenda, location, goals to critique against, models to be presented, invite critiquers, set key roles) b) Critique Goals: these are the goals established by numerous stakeholders of the business and design process, learning goals, UX and/or UI design goals) c) Discussion: includes ways of discussing that is separate to a brainstorm or giving general feedback. Could include looking at use case scenarios, clarifying questions, avoiding using absolutes, design alternatives (but not problem solving) d) Post-meeting Actions: presenting feedback notes to keep everyone in the loop, publishing actionable tasks for follow up What does everyone think? @C3 @C6 @C1 @C4 @C5 Below is a more scenario-style case - any suggestions on smaller use cases? I'm going to try and come up with a component diagram for it if I get a chance. <link removed>
1498	@C5 I agree with both your suggestions! @C4 I think the PE has to show the dashboard because that's what the course designer interacts with more and needs to have it to make design decisions. I think we could integrate the LA report into the PE for the Course Designer to

	see, cuz we've already stipulated that the LA platform doesn't interact with the course designer, to my understanding!
1614	I think that component diagrams 1 & 2 are tackling different things, but also shared a lot of aspects. The first one doesn't include the design critique component, and the second one doesn't refer to the Learning Analytics. My suggestion is to integrate both diagrams; I'll do it and post it in the pull request for your feedback.
C#78	I had a go at modelling the component diagram for Augustina's Internet of Things use case. I know her pull request hasn't been finalised yet but I thought I would add this to the consideration and it can be modified as we go along.
C#81	I'm proposing the following: - Delete this title: ## Component Diagram 2 based on Use Case Scenario - Integrate the descriptions of the layers from CD 1 and 2 - Change the URL to visualise the CD 3 (now is the CD 2) - Some cosmetic changes
1795	I think these changes are good. The only thing I'm thinking might be needed (though it may also be overkill) is an arrow from Learning Environment to the Internet of things to show that's what's displayed and the learner is interacting with.... something like this: <link removed>

Team C engaged in feedback activities at team and individual levels. For example, seeking and acting on group feedback can be seen in the discussions around whether the to use “Repository” or “Depository”, which had been interchangeably in document drafts. The meeting notes at commit 8cb310f record “Group consensus reached on use of REpository rather than DEpository. Needs to be updated across all models and pages. ACTION: All”. We can then see the group’s decision enacted by individual team members C6 at commit 1bacd6c on the use-case narratives and C3 at commit 522df2f on the component code and at 3e9cb70 the diagrams, with further consistency checking occurring prior to task submission.

Figure A87 shows that Team C were also able to manage when feedback indicated their work was not what they intended. At C#40, C6 asks for feedback on their interaction diagram, only to realise from C3’s response that they have updated the wrong model. Liberal use of capital letters, emojis, punctuation and sharing of the pressures of university work follow and the issue is closed without issue.

Figure A87: Partial screen shot from C#40 illustrating empathy in the feedback process.

Team C also valued all team members' contributions, with Table A62 below showing explicit references to team members evolving ideas that others have proposed.

Table A62: GitHub interactions showing development of other team members' ideas.

Reference	Comment
C#6	Used [C6]'s suggested workflow ideas to create a model of it in PlantText
3c6b52bf	Updated the model based on the feedback received and the Design Critique incorporating [C4]'s model
C#78	I had a go at modelling the component diagram for [C3]'s Internet of Things use case. I know her pull request hasn't been finalised yet but I thought I would add this to the consideration and it can be modified as we go along.
1655	lol @C1 don't we have a separate model for LAP already? yeah, I made it! but I have my doubts about it 😟 I agree, that should be reflected in a use case for LAP and the interactions for LAP @C4 why don't you open 1 pull requests

	with these additions in the use case for LAP? when you do that I will edit the interactions for LAP, you agree?

Regulative dimension of actions

Projective

There is evidence of a structured approval process which evolved over the course of the project, as seen in Table A63. The team continues to negotiate this process in the early days of the project, commenting at 1229, "Hi @C2 -I was waiting for us to establish our use case before completing this task. Should I not be adjusting this interaction diagram to better reflect your adjusted use case #1? I just merged the usecase.md thinking we had confirmed it. Apologies if I shouldn't have!".

Table A63: Interaction data showing evidence of a deliberate collaboration strategy.

Reference	Comment
1197	I won't merge any pull requests anymore until we all agree on which model to render.
1232	Also, my notes from the last meeting said that we were to make branches with "week 8", etc. and then go through all the pull requests together as a team and decide which ones to merge, but it seems that we have merging happening everyday.... Maybe we need some clarity as to which things can be merged immediately (eg. Readme, Minutes) and which things need to be discussed in a group before merging (eg. models)?
1234	I don't think there should be any merging until we define it in a meeting all together. Like we agreed last week, all of us work on our branches and leave the models on Pull Requests, then we merge during the meeting. Create your own branch with "week 8" and leave them on PR repos.
1239	I will also add a point in the agenda to confirm our merge processes. We did change the process last week but due to all the confusion I am not surprised we are all not on the same page yet. As this weeks facilitator I thought at one point that I should be merging, but the I remembered we agreed that we wouldn't merge until after the tuesday meeting. We are slowly getting there! Not to worry :)
C#51	[changed to 2 members approving]
1296	We'll wait for a few more people to see and approve. However, which pull request then gets approved? I'm assuming your edited copy?
1310	I've noted it and wait to see if anyone else has any changes before I update it.
1335	Remember the person creating the pull is the one merging upon approval of 4 members, so it's Dom's turn to merge it :) Cheers!

Regulative

Although the team experienced some difficulties with the GitHub workflow in the early stages of the project that is visible in several issues, for example, C#17, where they are concerned with locating a particular version of a diagram, narrative or code, Team C continuously monitored the quality and coherence of their knowledge objects throughout the project as shown by the interactions excerpted at Table A64.

Table A64: GitHub interaction data showing conscious monitoring of object development and quality.

Reference	Comment

C#27	Hi guys, I looked through the Use cases.md and it was a bit chaotic because there were images that didn't connect with the uml and 4 models with some missing narratives. I've condensed it to 2 models: an ideal design and an achievable design (as per the assessment). @C4 could you please add a narrative for your use case model?
C#58	I updated the AI Adaptive LD System Interactions Diagram to match the use scenario and also made a few edits to the rest of the page to make it consistent. I also added the links to other diagram that it may connect to. Also could whoever did the Learning Analytics Platform Interactions model * expand on narrative *fix image link that is broken
1534	Yes, I have changed my LAP interactions diagram to fit the Use Case Scenario and now it's fitting yours too! So it looks much more linked now. If you guys vote for merging my proposed LAP interactions diagram then it will reflect better your changes on this new parent interaction diagram @C64177
C#59	I edited my interactions model ad added links to other models it may connect to. What do you think of this format? Found here: <link removed> Code is: <code removed> I think it is important for all names to be consistent. I changed my name from Interactions Diagram #1 to AI Adaptive LD System Interactions Model to match [C2]'s model. I also changed the title of the model to reflect this. I am adjusting as many current diagrams as I can now but I am writing a checklist for everyone so they can make any future changes themselves.
1531	Hi [C4], I liked the wording. I'm adding depth now to my component diagrams that I modelled. Just take into account the change from "depository" to "repository" in your wording as we agreed upon in yesterday's meeting. Cheers!
1517	Also component diagram 1 & 2 looks as if they may be the same. I think #2 is an update of #1 so 1 needs to be deleted. @C3 is this yours? Can you also expand on the narrative e.g. what are the specific controller layers, what do they connect to? And add links to corresponding models. @C4 did you do the Learning Analytics Platform Component Model? Could you please expand on the narrative as above?
C#64	I just went through our documents and did some cosmetic changes and tagged you in some pull requests so you can fill in any data that may be missing. You were all probably going to do it anyway I just thought I would flag anything I came across as I was looking for consistency.
C#65	Hi guys, I made many changes to this repo, following the logic of the main use case scenario "Adaptive LD System". 1. I've eliminated Component #1 as per [C4]'s request since it was an outdated model, so I replaced it by the Component Diagram #2 which is now #1. 2. I added a narrative to #1. @C4 would you mind taking a look at the "Personalisation Layer" description? I'm not sure if the narrative reflects the components you modelled from which I fed to create that layer. 3. I've changed narrative of Component Diagram #3 "Component Diagram based on Personalisation Engine".

	4. I haven't added narrative to "Component Diagram #2 based on Learning Analytics Platform" because I didn't model it and I think the one who modelled it should add the narrative.
C#66	I changed the diagram to only fit the Use Case Scenario model because when I compared it to the Parent Interaction Diagram it didn't follow the same logic. In the parent interaction diagram the Learning Analytics proposes resources and searches the web for resources and I don't think that's something the LAP should do. I think yesterday we agreed that the LAP will only feed data to the Personalisation Engine and Cloud Repository and in such a case the PE will interact with the web to search for resources. We need to change the *Parent Interactions Model* to reflect the changes we agreed upon yesterday in terms of the LAP behaviour that Daniela suggested.
1835	Not everyone has linked to corresponding models yet so please do so ASAP. You don't have to link to every model, only the one that makes the most sense.

Appendix I

Team C Issue 86

Course Design with Smart Functionality #86

Merged [redacted] merged 2 commits into master from [redacted]177-week12 on 27 May 2019

Conversation 12 | Commits 2 | Checks 0 | Files changed 1

[redacted] commented on 22 May 2019

Thought I would put this up for discussion. I ended up doing a use case without AI as an actor because it didn't need to be.

What if the entire LE has smart functionality, as stored user data and made decisions within the platform without an other actors interfering?

What if a CD and COP only added to the repository? So was able to elevate the experience by providing more resources for AI to read from? I think this is a good start but could be expanded upon. Especially if Daniela has her own ideas coming out of the research she has done.

Let me know of your thoughts.

Course Design with Smart Functonality ··· a845abf

[redacted] requested review from [redacted] on 22 May 2019

[redacted] commented on 23 May 2019

[redacted]

I like this concept and very clever the way you were able to do it without AI being an actor! :-). I think to make it align though with the other models you might need to change it slightly so that the focus is on the Personalisation Engine (where we have the AI sitting in the other models) and then that leads to the Learning Environment. But then I wonder if this is really any different to the other models we created??

I took a crack at changing it around - not sure if we really need both the course and the Learning Environment in this model though - is it the same? Anyway, have a look here and see what you think:

https://www.plantuml.com/plantuml/img/dP91Yy8m48NI-HLpj8V-WqKKgx1GiEmUzbXY7Ri3pKIlYMx_lMEh868zx2tC-zvxoP1551iakSu8lOUmyYb4X08ZjGndab_uTah09d4Zdcr7qfkHgaSA0zW8gqAdpYLMlTuUwYhOHgZ1GTjMfaGRRcXfJ9ddSvWDC-8MrdoYuDaXltRJnehicLpg3NhDZPcv8p0TfSKmfdK-xU4BZpwl-D2hL4mfimf375uQhP1dZMo9jUVZVuOVt6Km3RtPnBJdOK7tGpv_lQKNmy7_jwm-trTS2RD0tkltk000

And here's the code for it if we want to use any of it later:

```
@startuml
title Course Design with Smart Functonality
Course_Designer as CD
Community_Of_Practice as COP
Learner as L

L--> (Learning Environment)
L--> (Course)
L--> (Learning Analytics)
(Course) -> (Learning Environment)
COP --> (Cloud Repository)
CD --> (Cloud Repository)
(Personalisation Engine) <--> (Cloud Repository)
(Personalisation Engine) <--> (Web)
(Personalisation Engine) --> (Learning Environment)
(Personalisation Engine) -> (Course)
(Course)->(Learning Analytics)
(Learning Analytics) -> (xAPI)
(Personalisation Engine) -> xAPI
@enduml
```

[redacted] commented on 23 May 2019 • edited Author

Thanks Maddie! Maybe I could represent it in a different way as my original thought process was that it is more of a "AI learning engine" where the user logs in, sets their own parameters, AI looks through CCR (added to by COP & CD) & Web for data and pulls it back into LE to be acted upon by the learner. How else might we represent this so that it is clear that all that functionality is happening within the same environment? I agree if we start separating the PE out again that it just becomes like our original models, so trying to make this more futuristic!

[redacted] commented on 23 May 2019 • edited Author

Just realised that my original diagram is also missing an arrow from PE to Course. The reason that I haven't included a Learning Analytics Platform is that I kind of thought xAPI could be used to store/organise user data to be processed and acted upon by our Smart AI Learning Engine rather than having to be served to an outside actor to be acted upon.

[redacted] commented on 23 May 2019

[redacted] - Ah I see - so the student can create their own course? Cool idea!

In that case, what about using one of the other models we already have but change the arrow and actor so that it is the student entering in the info into the PE instead of the course designer. then the rest could sort of stay almost the same. So the student enters in the parameters into the PE, the PE gathers info from that particular student's Learning Analytics and xAPI, then looks in the repository and web for course materials and activities and then creates a course for the student? You could use the sequence diagram for course set up and just change the course designer to the student, remove the experts and anything related to the design critique and voila!

[redacted] commented on 24 May 2019

[redacted] - Hiya - I had another thought about this... based off Quang's idea of Coach U. You could do a sequence model that starts with the learning analytics. The Analytics sends a particular student's info to the Personalisation Engine and what further learning that student needs. The PE then searches the web and repository for appropriate materials and activities then creates a customised Learning Environment/ course for the student. LA-> PE -> Rep/Web -> LE
Not sure this would work as a use case since the student doesn't come in till the end, but I suppose it could...
Just an idea...

[redacted] commented on 24 May 2019

Hi [redacted]

Maybe we could add in your model a rectangle called "Learning_Analytics Platform", which can be related to the "Learning_Environment" through the xAPI. Thus, the LAP feeds the PE (or Pedagogical recommender system) with data about the students and also about the effectiveness of the learning design model used for that educational context. With this dynamic, the system (the PE) could be able to store, reuse and compare pedagogical scripts for future course design.
Just my thoughts. We also could keep what we have so far.

[redacted] commented on 24 May 2019 Author

Thanks!! Let me know what you think of this. I have had an issue at work and now have to work all weekend (WORST TIMING!!) so probably won't be able to do much else. Maddie I wasn't planning on doing an interaction diagram anyway as I am doing the use case (my first one!). I don't think this model has to be based on our previous models as its futuristic. Maybe this doesn't go far enough! Maybe someone else can have a crack at it if they think they can take it even further. My brain just goes straight to total removal of humans and users making all the choices, rather than designers.

https://www.plantuml.com/plantuml/img/XPB1QiCm38RlUWeTwqFUO9IMf8D1e6Oxx1YyLCqCiLniULiOU_SvIGEx93IPwF_a_xViGnGJ9BaUGApqXALF8H9M56t7-6db7LzSHI0nSIkUJMzb09YnPiOee8bOLhdgNE8CDETheuDfnROqQMSDDPbmHsk0GAqOxhBZLBVSDlV-iC6p8nRyHjXf2d4oZ4QiPpnnPvbKLcPt1Jy0TL7iSGszgmiEEGREbTwd2pxJpKShFWmAocfDMG-orl1FnokzgOth_KsyR8hzxkkedzHcrqXayt6P3ba6YyVC3_af8khUoDK7D_floWzRKuK3yIN_cLy0

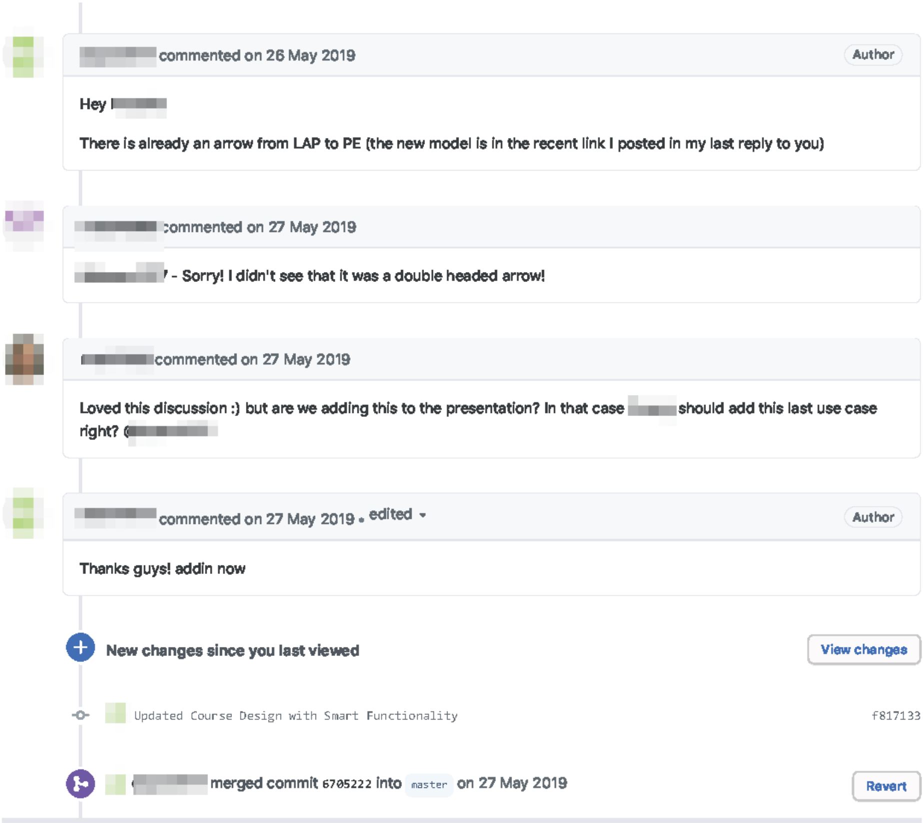
Learner enters the Learning Environment interface and inputs constraints such as duration, requirements, interests etc into the Personalization Engine (with AI) to generate a bespoke course. The Personalisation Engine gathers data from the Web and the Course Cloud Repository, which is constantly updated and reviewed by a Course Designer and a Community of Practice (if in the future we even need this!). The Learner actions the course and the user experience is logged by xAPI, the data is stored in a learning record store on the Learning Analytics Platform which is analysed by the AI in the Personalisation Engine. The Personalisation Engine then updates the course based on the Learners needs (no CoachU needed as AI does it all and interacts directly with the course).

https://apifriends.com/api-management/api-and-artificial-intelligence/
Worth a read!

[redacted] commented on 25 May 2019

[redacted]

Hiya - yeah that model looks good for the student to be an initiator. I wonder though if it would be cool to also have an arrow going from the learning analytics back to the PE so that it is an idea that while the student is taking the first course, the data is being collected and analysed and then the analysis is feed back into the PE for further customisation for the next course or for additional activities? Just a thought...


[redacted] commented on 26 May 2019 Author

Hey [redacted]

There is already an arrow from LAP to PE (the new model is in the recent link I posted in my last reply to you)

[redacted] commented on 27 May 2019

[redacted] - Sorry! I didn't see that it was a double headed arrow!

[redacted] commented on 27 May 2019

Loved this discussion :) but are we adding this to the presentation? In that case [redacted] should add this last use case right? [redacted]

[redacted] commented on 27 May 2019 • edited Author

Thanks guys! addin now

New changes since you last viewed View changes

Updated Course Design with Smart Functionality f817133

[redacted] merged commit 6705222 into master on 27 May 2019 Revert

Appendix J

Team B Issue 27

Design Critiques - for group discussion #27

Closed [redacted] pened this issue on 1 May 2019 · 10 comments

[redacted] commented on 1 May 2019

Please contribute your thoughts on the below questions regardng critiquing designs. You can base your comments in a general sense, however we will also be looking and reviewing use case 2 as our most advanced model:

1. Does this model allow for appropriate collaboration? (design languages, scripts)

2. How does design manifest intent? Intent =2025. Has this been achieved?

3. Is there clarity in the design? Do all users understand their role in model?

[redacted] commented on 3 May 2019

Here are my initial points- in summary I think we have the bones but I think the richness of our ideas our not as powerfully visible as they could be:

- In terms of collaboration, I think there are two different elements. To encourage collaboration within the learning design activities, ie students do activities with collaboration points there needs to be planning and set points within the learning design to facilitate this. We had planned this in our original use case scenario 2. However, what is missing is any explicit mention of how a user could have input into the design during the design process and while using, and how explicitly they could adapt a design to suit their needs more.
- Also, should the student be able to give feedback on the learning design?
- Re 2025: it isn't clear what our futuristic elements are from the diagram. We reference AR/VR/ITS/Video but most of this is existing now. I think we saw the analytics and adaptive as forming part of the futuristic side, and perhaps an AI generated/suggested learning path but this isn't so clear as to when & how.
- related to points above, i think the role of the teacher could be more integrated with the role of the designer earlier on and as an ongoing process of feedback.

[redacted] commented on 3 May 2019

My thoughts on our work so far:

1. Does this model allow for appropriate collaboration? (design languages, scripts)

- The feedback loop, meta-designer -> teacher (main user) -> student, is not as explicit as we wanted. The communication lines between the meta-designer and the teacher are quite vague.

2. How does design manifest intent? Intent =2025. Has this been achieved?

- The main challenge is how to find the balance between employing high-tech tools like machine learning but still preserve the important role of the teacher in the whole process. I guess we need to decide which question we are trying to answer: (1) In 2025, can tech help teachers become instructional designers without training?, or (2) In 2025, will we still need teachers if machine learning can facilitate the generation of personalised learning experiences?
- If we choose to answer the first question, I think our model can empower teachers to become expert-level instructional designers by 2025. The job of the meta-designer would be to create scripts to make sure that the "AI" in the system will feed the correct data to the teachers. The role of the meta-designer in authoring these scripts wasn't explicitly shown in our diagrams.

"should the student be able to give feedback on the learning design?" - This is a challenging question **@lmcl2011** I think student feedback should only be at a usability level because they are not experts on instructional design.

3. Is there clarity in the design? Do all users understand their role in the model?

- The meta-designer's role is not very clear.

1

[redacted] commented on 3 May 2019 Author

Great stuff so far guys! I think we are gettinv closer to it!

1. Does this model allow for appropriate collaboration? (design languages, scripts)

At the current stage, I dont think it does. I think there needs to be more collaboration between the designer and the teacher to really try and define 'what is it that teachers needs' and from the teachers perspective 'how to leaners learn best'.

2. How does design manifest intent? Intent =2025. Has this been achieved?

I like Paola's second point of getting teachers trained up as instructional designers. This is someting that is achieable within the next 5 years, if that was a key focus. I think it ties in well with trying to ensure data is used, especially if it is automatic and not onerous. At the moment, when data is done through surveys, it relies on learnes answering surveys and then the teacher checking and implemeting changes, which does not always happen!

3. Is there clarity in the design? Do all users understand their role in model?

At this stage probably not. Through further collaboration between designers and actors, perhaps the parameters can become clearer. Also do we need to add students to this use/case?

[redacted] commented on 5 May 2019

1. Does this model allow for appropriate collaborations?
I agree that there needs to be more collaboration between the teacher and the designer. Having said that, if the designer simply develops the shell/skeleton for activities/assessments, then the teacher can adapt it to suit their course without having to go back to the designer (if they have appropriate training).
In response to Lucy's point, I think that the student should be able to give feedback on the learning design. Fischer (2014) terms this a participatory design approach and talks about empowering users to propose and generate design alternatives. I think this could be achieved through a feedback tool in the web application. The teacher could set it for weekly, fortnightly etc. The data could then be collected and used to inform re-design with the teacher ensuring that any redesign is pedagogically sound.

2. How does design manifest intent?

Thinking further on Paola's second point, I think we also need to think about training teachers in how to analyse data. The brilliant aspect of a LDE is that there is so much data to be gathered. How do we ensure that teachers know how to break this data down and then have it inform instructional design.

3. Is there clarity in the design? Do all users understand their role in the model?

Yes, we need to include the student/learner in our use case to demonstrate their relationship with the use cases.
I also agree with Lucy about the integration of the role of the teacher. I think we need to make this more of the focus, rather than what the designer is doing.

I think we need to look at breaking this use case down further (as Peter suggested in the lecture) to make the users and relationships clearer. As we break it down, I think we could put more detail into it. For example, what data are we collecting and how does that feed back into the design loop? (see below) I'm more than happy to work on this going forward :)

Define data to collect --> activity completion
--> assessment results
--> course completion (course progress)
--> time on session
--> content views (ie how many times students are accessing content)

Not sure if this is going into too much detail??

👍 1

[redacted] commented on 5 May 2019

Hi everyone, here are my thoughts

1. **Does this model allow for appropriate collaborations?**
   Definitely not. Were we asked to include collaboration elements at the outset or just to define roles and actions? I find that asking us to design use-case based on the idea that a future learning designer will press a button and out comes a learning design, incongruous with the concept of collaboration between teacher, student and designer. Anyway, as far as I can see collaboration could be included from the outset and throughout the whole process. Lines of communication need to be open between all three actors in the system, the student is in communication with the teacher and the learner designer relaying back to them their experiences. The teacher then acts as an 'interpreter' of the student's experience and the learning designer can act as a 'problem solver' redesigning the learning experience as it progresses. AI could assist with this process by providing additional data which can be triangulated and used by the teacher and learning designer to provide a targeted learning experience.

2. **How does design manifest intent?**
   Yes to the points above about teachers needing to analyse data and realise that they are no longer the sole drivers of content/information. I think teachers already are acting as learning designers (detailed programming is essentially learning design), they just may not realise it yet.
   I am uncomfortable with the **lack of student direction** in the use case, as from my research this is going to be heavily factored into learning experiences in the future (particularly in higher ed). Look at how much agency we have been afforded in this course (and others offered through the MLS&T) we are essentially able to chose topics to pursue and are assessed on our learning process rather than content knowledge (predominantly). Maybe the needs to be factored in?

3. **Is there clarity in the design? Do all users understand their role in the model?**
It was a draft, there is definitely not clarity in the design. The teacher only comes in towards the end of the design process and needs to be more involved from the beginning. I believe the **teachers role will be that of a 'human factor'** - a point of contact and an essential element in future learning designs to assist with engagement of the student and mediate collaboration between students. Present elearning experiences that lack a 'human' element (such as MOOCs) are known to have high incompletion rates. In light of this, the teacher's role could be that of an observer, a coach and a problem solver (as discussed before). As mentioned earlier, the technicalities of the learning design can be dealt with by the designer.

[redacted] commented on 10 May 2019

Hi Everyone,

One of my tasks for this week was for [redacted] and I to "*Design Critique Peter's ticket - Make your ideas for including design critique in an LDE concrete by specific use case and interaction sequence diagrams*".

I have gone to do this and realised I am not completely sure what it means - because I feel that our second use case "at a micro level" does this well. Sorry if I have misunderstood what I needed to do. Any suggestions/clarifications would be very appreciated!

Thanks,
[redacted]

[redacted] commented on 11 May 2019 • edited

Hi [redacted]

I think it means including our previous critiques within the uses cases and sequence diagrams (collaboration, intent etc)
I took it also to mean including points for the student and/or teacher to critique the learning design. I will take a look at the most recent use case and sequence diagrams and see if I can insert points for critique today.
Team- is there a particular paper we should reference for this activity (other than Fischer)?
Thanks and all the best,
[redacted]

[redacted] commented on 11 May 2019

[redacted] We don't have a sequence diagram for the design critique, so that is also needed.
I'll spend some more time tomorrow afternoon responding to pull requests.

[redacted] commented on 11 May 2019

Thank you [redacted] I will create something by tomorrow morning

[redacted] commented on 12 May 2019

I think [redacted] has created what we needed - but I could be wrong. Please let me know if I am.

[redacted] mentioned this issue on 22 May 2019

Issue on closing Issues #72 — Closed

[redacted] closed this on 24 May 2019