Co-designing a contextualised outreach initiative to attract females into computer science: A Change Laboratory with a school-university partnership

Fiona Redmond BSc, MSc

May 2025

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

Department of Educational Research,

Lancaster University UK.

Abstract

The underrepresentation of females in computer science has prompted numerous outreach initiative designs and design principles, yet much of this work overlooks the role of local context and stakeholder collaboration in designing these programmes. While the literature highlights strategies like early exposure, short-term interventions, and specialised curricula, it often lacks a clear understanding of how these approaches can be adapted to meet unique community needs. My research addresses this shortcoming by documenting the development of a local, contextualised initiative and examining how contributions from different stakeholders shaped a design that directly addressed challenges within a given practice context. This approach offers insights into promoting sustained female engagement in computer science through co-designed initiatives.

This project is built on an existing university-school partnership, leveraging it as a foundation for co-design efforts. Using a Change Laboratory approach, I facilitated workshops where stakeholders collaboratively designed an outreach programme aimed at increasing female participation in computer science, tailored to the local school's needs, resources and culture, alongside a complementary university activity system. The outreach programme was designed using activity theory and Engeström's expansive learning cycle, identifying and addressing challenges specific to the local context. Data sources for the analysis include workshop recordings, artefacts created during sessions, and reflective diary entries, which are analysed to trace the design's evolution and provide an account of how collaborative design enables contextually relevant outreach.

Findings reveal that the collaborative design process led to a proposed progressive three-year curriculum aimed at fostering continuous engagement in computing. Stakeholders prioritised a structure delivered by familiar schoolteachers that includes site visits and mentorship, progressively building students' skills and confidence. This structure was proposed to foster a sense of belonging considered essential for sustained interest, to address local resource gaps and challenge gender stereotypes, promoting local ownership and responsiveness. The design emerged from stakeholders identifying and seeking to address local contradictions, such as the need for sustained engagement beyond one-off events, guiding the development of mentorship and progressive skill-building to strengthen students' experience and confidence over time.

This research makes a range of contributions to the literature on outreach to promote female participation in computer science, offering insights into linking early exposure with long-term support and integrating progressive curricula that offers comprehensive computing education aligned with students' specific interests. By providing evidence of how identifying contradictions can inform sustainable, responsive programmes, this study highlights the value of context-specific interventions. Emphasising the collaborative design process, it demonstrates the value of bringing together diverse stakeholders to create culturally relevant outreach initiatives that respond to specific contextual needs, potentially supporting greater engagement and inclusivity in computing.

Table of Contents

Acknowledgements

This PhD journey has been both an academic and personal endeavour, and I am deeply grateful to those who have supported me along the way.

I would like to express my sincere gratitude to my supervisor, Dr Brett Bligh, whose insightful feedback, thoughtful critique, and unwavering support were instrumental throughout the entire process of this research. Working with him has been a genuine pleasure. His generosity with his time, along with his patience, motivation, and immense knowledge, is something I will be forever appreciative of.

I extend my sincere thanks to my examiners, Professor Nick Hopwood and Dr Bethan Garrett, for agreeing to examine my thesis and for providing me with the opportunity to discuss my research.

I would like to thank South East Technological University for supporting me in this journey. I am also grateful to my colleagues in the Department of Computing whose encouragement and interest in this work helped sustain me throughout.

I am extremely grateful to the participants of this research. Your willingness to share your experiences and insights has been crucial to the success of this study. Thank you for your time and for allowing me to learn from your valuable contributions.

I would also like to extend my sincere thanks to Tullow Community School, especially Cleona McCann, for your engagement and collaboration throughout this research. Your openness and commitment to the initiative made this work both possible and meaningful.

This PhD would not have been possible without the unwavering support of my family and friends.

To my parents, Willie and Marian, and my sister, Marguerite, thank you for always being there and for your constant support. To my late brother, Richard, whom we lost suddenly in 2023 - your memory has been with me every step of the way since.

Finally, to my husband Michael, thank you for your enduring belief in me, your patience, and your steady encouragement. I am forever grateful and I hope I can return the favour. And to our children, Hannah, Kate, and Tadhg – thank you for your love, patience, and for keeping me going.

List of Figures

List of Tables

List of abbreviations

AS	Activity System
CHAT	Cultural Historical Activity Theory
CS	Computer Science
CSE	Computer Science Education
CT	Computational Thinking
DIRWG	Diversity and Inclusion Recruitment Working Group
HE	Higher Education
HEA	Higher Education Authority
HEI	Higher Education Institution
HEREE	Higher Education Research Evaluation and Enhancement
HOD	Head of Department
ICT	Information and Communication Technology
ITC	Institute of Technology Carlow
JCPA	Junior Cycle Profile of Achievement
LCCS	Leaving Certificate Computer Science
NCCA	National Council for Curriculum and Assessment
SDG	Sustainable Development Goals
SETU	South East Technological University
STEM	Science, Technology, Engineering and Mathematics
TADS	Transformative Agency by Double Stimulation
UN	United Nations
UNESCO	United Nation Educational Cultural and Organisation
WIT	Waterford Institute of Technology
ZPD	Zone of Proximal Development

Publications derived from work on Doctoral Programme

Redmond, F. (2021), 'Lecturers' Perceptions of the Leaving Certificate Computer Science Curriculum and its Influence on Higher Education in Ireland', The All Ireland Journal of Teaching and Learning in Higher Education (AISHE-J), Vol. 13, No. 2.

Redmond, F. (2022). With a Rise in Computing Disciplines Comes a Greater Choice of Computing Degrees in Higher Education. In Koli Calling '22: 22nd Koli Calling International Conference on Computing Education Research (Koli 2022). Association for Computing Machinery, New York, NY, USA, Article 5, 1–11. https://doi.org/10.1145/3564721.3565946

Redmond, F. (2022). The Co-Design of An Outreach Initiative to Attract Females into Higher Education Computer Science. In Proceedings of the 27th ACM Conference on Innovation and Technology in Computer Science Education Vol 2 (ITiCSE 2022), July 8–13, 2022, Dublin, Ireland. ACM, New York, NY, USA, 2 pages. https://doi.org/10.1145/3502717.3532118

Redmond, F. (2023). Project management of an online Change Laboratory using Notion. Bureau de Change Laboratory. https://doi.org/10.21428/3033cbff.7c027366

Use of Generative AI

I acknowledge the use of AI tools during this research. Otter.ai (Pro version) was used for initial session transcription, which I manually reviewed and corrected. I used ChatGPT (OpenAI, GPT-4, accessed between 2024-2025) to assist with language refinement, restructuring, and generating .ris files for referencing software. All writing, analysis, and final decisions remain my own.

Chapter 1 Introduction

1.1 Introduction

This thesis explores the co-design of an outreach initiative aimed at increasing female participation in computer science (CS) at higher education, with a particular focus on addressing gender imbalances in the field. Despite decades of awareness and intervention efforts, women remain significantly underrepresented in CS education worldwide, a disparity with profound implications for equity, innovation, and economic development[1]. Research consistently highlights that diversity of perspectives is essential for tackling complex challenges, fostering innovation and creating inclusive workplaces (Page, 2007; Google, 2024). Recent work on the Morecambe Bay Curriculum illustrates how regional educational reform can be driven through cultural change embedded in local partnerships (Garrett and Nelkon, 2024), a theme echoed in this thesis.

Many outreach programmes designed to increase female participation often rely on short-term interventions, such as one-off workshops, coding boot camps, or generalised curricula (Lyon and Green, 2021). While these initiatives may raise awareness or spark initial interest, they frequently fail to address the broader structural and cultural challenges that deter women from pursuing CS. For instance, systemic barriers including persistent gender stereotypes (Cheryan *et al.*, 2013), a lack of visible role models (UNESCO, 2017), and limited access to sustained mentorship or peer networks (Higher Education Authority, 2022) remain significant deterrents. For outreach initiatives to be truly effective, they must extend beyond generic solutions and be responsive to the specific needs and contexts of the communities they aim to serve.

This is where the co-design approach becomes particularly relevant. By actively involving a diverse range of stakeholders, including educators, industry representatives, students and community members, co-design attempts to ensure that initiatives are grounded in the lived experiences and aspirations of the target group. Research highlights that co-design fosters collective creativity, empowering participants to develop solutions that are more relevant and impactful (Sanders and Stappers, 2008; Hopwood *et al.*, 2024b). The value of school university collaboration in transforming practice across different national contexts is highlighted by Hopwood's recent international work in Australia, Nepal, and Bhutan (Hopwood *et al.*, 2024a), reinforcing the

[1] https://unesdoc.unesco.org/ark:/48223/pf0000384678

importance of locally grounded, yet globally resonant partnerships. Moreover, it prioritises relational practices, shared understanding, and iterative problem-solving, elements that are crucial for addressing the multifaceted barriers women face in CS.

For this study, co-design is not just a method but a necessity for creating meaningful and sustainable change. Traditional top-down approaches often overlook the nuanced ways in which local cultural, educational, and institutional dynamics shape female participation in CS. By engaging with stakeholders through co-design, this research aims to develop an outreach initiative that resonates with the specific context it seeks to impact. Ultimately, the goal is to demonstrate how co-design can move beyond surface-level interventions to tackle systemic inequities, creating a more inclusive and representative future for computer science education.

The central aim of this thesis is to document and analyse the co-design process of a locally tailored outreach initiative to promote female participation in computer science. Understanding this process is crucial because it sheds light on how collaborative approaches can address complex, context-specific challenges in education. As Bligh (2024) argues, co-design within Change Laboratory frameworks allows participants to not only develop tools and practices for learning but to reimagine the activity systems in which they work. By analysing the co-design process, this research provides insights into potential strategies and pitfalls, and the role of diverse stakeholders in creating impactful outreach programmes.

The research site, a partnership between a university and a secondary school in Ireland, provides an invaluable context for this work. This collaboration bridges the gap between higher education and pre-college learners, allowing for a deeper understanding of the barriers faced by female students as they transition to CS studies. Furthermore, the Irish context presents a unique opportunity to explore these dynamics in a country where gender disparities in CS reflect broader global trends, yet are also shaped by local cultural, educational and institutional factors. By examining this specific context, the thesis aims to produce findings that are locally relevant while also providing insights that are potentially transferable to other settings.

Conducted online between March and June 2022, this project engaged 15 participants, including university faculty, management and undergraduate students and secondary schoolteachers, in a structured Change Laboratory intervention. Guided by the principles of activity theory and expansive learning, this method facilitated a series of collaborative tasks, such as questioning, analysis, modelling, and examination, that enabled participants to critically explore local barriers to female participation in CS and co-design a locally tailored, progressive outreach curriculum.

Before this research project, the university's Department of Computing engaged in outreach efforts aimed at promoting diversity and inclusion in CS education. However, these efforts were largely short-term, lacked structure, and did not establish long-term partnerships with specific schools. Similarly, the secondary school offered computing as a subject in first year but provided no further computing options until senior cycle. Uptake at that stage remained low, particularly among female students, due to limited exposure, a lack of structured support and persistent gender stereotypes.

Through the Change Laboratory process, these two activity systems were brought into interaction, forming their partially shared object. The shared object came from independent goals to a unified focus on creating an outreach initiative that better aligns with their specific needs. This integration addressed previously unmet needs, such as continuous exposure to CS concepts in the school and gender imbalance in undergraduate computing programmes in the university's computing department, and a focus on building confidence and a sense of belonging over time.

As a result of the Change Laboratory process, stakeholders co-designed a three year curriculum to be delivered by familiar teachers within the students' existing educational environment, ensuring continuity and relevance. Unlike conventional outreach programmes, which are often externally imposed and short-lived, this stakeholder-driven initiative leveraged the expertise and insights of both school and university representatives. Rather than focusing solely on technical skills, it presented computing as a diverse and creative field, countering misconceptions that often deter students from engaging with the subject long-term.

A key distinction in this locally designed CS initiative is its emphasis on collective engagement rather than individual student interventions. By focusing on entire student year groups, STEM teachers at the school identified and addressed common misconceptions about computing at scale, rather than focusing on isolated student experiences. This approach enabled the outreach initiative to reshape how students perceive computer science, moving beyond narrow associations with coding or IT support and instead highlighting its broad applications across multiple disciplines.

At the university level, the outreach initiative designed through the Change Laboratory process aligns with the Department of Computing's broader goal of fostering a more diverse student cohort. The DIRWG recognised that traditional recruitment strategies were not significantly shifting gender imbalances. By partnering with the school, stakeholders involved in the Change Laboratory aimed to co-design a long-term, embedded approach to outreach, one that not only introduced students to computing but also fostered a sustained interest over time.

While the outreach programme resulted in tangible outputs such as mentorship opportunities, integrated curriculum elements and university-school site visits, this thesis focuses not on evaluating the programme itself, but on the co-design process that led to its development. By examining how different stakeholders navigated challenges, negotiated shared goals, and iteratively refined their ideas, this research offers insights into how expansive learning can be leveraged to design more sustainable, impactful computing outreach initiatives.

This thesis argues that the success of outreach initiatives in computer science is not solely determined by their content but by the processes through which they are designed and developed. Rather than advocating a prescriptive model that can be replicated in any context, this research examines how collaborative co-design unfolds over time, embedding local insights and stakeholder perspectives into the eventual locally designed CS initiative. The findings reinforce the need for shared ownership and systemic approaches that actively engage local actors in shaping solutions tailored to their unique challenges and opportunities.

The remainder of this chapter is structured as follows. Section 1.2 focuses on my personal motivation for undertaking this research, offering insights into the experiences and perspectives that shaped this study. Section 1.3 outlines the broader policy context, highlighting the key strategies and frameworks influencing efforts to address gender imbalances in computer science education. Section 1.4 explores the practice context, providing an overview of the educational and institutional settings in which this research is situated. Section 1.5 details the research context, focusing on the university-school collaboration. Section 1.6 presents the research questions that guide the inquiry, and finally, Section 1.7 concludes the chapter with an overview of the thesis structure, setting the stage for the detailed exploration in subsequent chapters.

1.2 Personal Motivation

This project reflects my larger professional goal of driving change in gender diversity within computer science (CS) education. As someone deeply invested in addressing the underrepresentation of females in CS education, I am motivated by both personal and professional experiences that highlight the scale and persistence of this issue. Throughout my education and career, I have observed how this disparity shapes classrooms and workplaces, influencing the broader culture of the discipline. Despite decades of outreach initiatives, the field of CS remains overwhelmingly male-dominated. Witnessing this imbalance first hand has fuelled my commitment to developing effective and sustainable solutions.

One experience that reinforced this motivation is my role as a leader in our university department's Women in Technology Society[2]. Each year, we struggle to recruit enough members to sustain the society, reflecting the low numbers of female students in our computing programmes. Despite efforts to create an inclusive and supportive space, the limited pool of female students makes it difficult to build momentum. This experience deepened my commitment to exploring systemic solutions that go beyond short-term interventions.

As a lecturer in the Department of Computing for the past seven years, my primary role involves teaching undergraduate computer science across a variety of programmes, including Cybercrime and IT Security, Interactive Digital Art and Design, and Information Technology Management. My expertise spans Linux systems administration, security, web development and human-computer interaction, giving me direct insight into the diverse learning experiences of students across different computing disciplines. One key observation shaping my motivation for this research is the blatant contrast in gender imbalance across these programmes and other programmes within my department. While the Interactive Digital Art and Design programme tends to attract a more gender diverse cohort, software development and IT management programmes remain overwhelmingly male-dominated.

Given my first-hand experience, I have long been an advocate for increasing female participation in computing, both through my teaching and through department-wide discussions on diversity and inclusion. My position as an insider within the department allowed me to engage effectively with colleagues and institutional stakeholders, fostering collaboration and ensuing alignment with departmental priorities. This familiarity with both the structural and cultural factors shaping gender imbalances positioned the computing department as a natural intervention unit for this project. It also gave me a unique vantage point to design an outreach initiative that is not only

[2] Instagram for Women in Technology Society, SETU Carlow https://www.instagram.com/setuwomentechcw/

contextually relevant but also informed by both institutional goals and lived realities of students and staff.

Despite general acknowledgement of the gender imbalance, no systemic approach has been taken to address it. Efforts remain piecemeal, such as distributing the limited number of female students across lab groups, but these strategies support existing students in an effort to retain them, and therefore don’t lead to significant change in enrolment. My commitment to gender equality aligns closely with our institution’s Gender Equality Action Plan, which explicitly aims to address gender imbalances in computing programmes.

Over the years, my frustrations with existing outreach efforts have further shaped the development of this project. My institution has implemented various campaigns, such as open events, school visits, and an annual Women in Computing and Engineer seminar for secondary school students. However, these initiatives have failed to yield meaningful, lasting change. Having participated in these initiatives, I saw firsthand how their short duration and lack of sustained engagement limited their impact. This observation aligns with research on the limitations of short-term interventions (e.g., Eidelman *et al.*, 2011). Through this project, I aim to address these shortcomings be developing a more coherent and theoretically grounded outreach model.

During my doctoral studies in the Higher Education: Research, Evaluation and Enhancement (HEREE) programme at Lancaster University, I examined factors influencing female students’ choices in CS. Through both coursework and original research conducted as part of the programme’s training modules undertaken in the first two years, I found that nearly half of female students enrolling on higher education computing programmes had no prior experience with computing (Redmond, 2022). This significantly affected their confidence and sense of belonging, a finding that aligns with broader research highlighting how a lack of early exposure contributes to lower self-efficacy among female students (Sharma *et al.*, 2021). It also highlights the urgent need to engage with students earlier, particularly in secondary school, when perceptions of CS are still forming.

Building on these insights, I chose to focus this project on a local secondary school, engaging students at this formative stage in their educational journeys. The decision to collaborate with one school, rather than a broader group, emerged from discussions with my Head of Department who connected me with a school that expressed interest in enhancing its CS education and outreach. This approach aligns with my university’s strong regional focus, where a significant proportion of our students come from the surrounding area, and institutional partnerships with local schools and councils are actively encouraged. Unlike universities with a predominantly international intake, our institution plays a key role in widening participation within the local community, making school-university collaborations a natural fit for outreach initiatives. The resulting partnership provided a strong foundation for co-creation, aligning the school's educational mission with the department's recruitment goals.

As Hopwood *et al.* (2024) suggest, school-university collaborations can serve as sites of expansive learning (Engeström, 2016a), where joint reflection and experimentation lead to innovative practices. This partnership seeks to mirror such an approach, leveraging the strengths of both institutions to address barriers deterring female students from engaging with CS. By documenting the complexities of the co-design process, I aim to contribute to a body of knowledge that informs future outreach programmes, equipping educators and outreach designers with the tools to create more contextually relevant CS initiatives.

1.3 Policy Context

This project engages with key policy domains that seek to address the persistent gender imbalance in computer science (CS) education. These policies span global frameworks, national strategies and institutional initiatives, reflecting a shared recognition of gender disparity as a critical barrier to equity, innovation and economic competitiveness. While high-level policies provide essential guidance, their ability to drive change often hinges on how effectively they translate into context-sensitive actions. This section outlines how global, national and institutional policy frameworks shape the broader discourse on gender imbalance in CS and considers how this research contributes to bridging the gap between policy intention and practical implementation.

At the global level, organisations such as the United Nations (UN), and UNESCO have identified gender equity in science, technology, engineering and mathematics (STEM) as critical to achieving broader development goals. For example, the UN's Sustainable Development Goals (SDGs), emphasise the elimination of gender disparities in education (Goal 4) and the empowerment of women and girls (Goal 5) as pillars for sustainable progress (United Nations, 2015). While many global frameworks often address STEM in general, computer science (CS) is increasingly acknowledged as a distinct area of concern, given its central role in economic development and technological innovation (UNESCO, 2017).

UNESCO's *Cracking the Code* report critically analyses the systemic barriers that hinder women's participation in STEM, including gender stereotypes, a lack of role models, and unsupportive learning environments (UNESCO, 2017). These insights are echoed in UNESCO's more recent *Gender Fact Sheet* (2023), identified as one of the fastest growing but most male-dominated disciplines in the world (UNESCO, 2023). These reports call for more targeted and contextually responsive approaches that go beyond generic STEM strategies.

In the Irish context, the STEM Education Policy Statement 2017-2026 (Department of Education and Skills, 2017) outlines a national vision for enhancing diversity and inclusion in STEM education. It stresses the importance of early engagement, collaboration across sectors and sustained support to improve participation among underrepresented groups. However its broad framing of STEM does not account for the discipline-specific barriers unique to CS, such as the persistent association of computing with narrow technical skillets or the continued underrepresentation of female students in post-primary computing classes.

To promote institutional change, the Higher Education Authority (HEA) has adopted the Athena SWAN Charter[3], encouraging higher education institutions (HEIs) to address structural inequities through data informed self-assessment and action planning. While the charter has catalysed important institutional discussions, its reliance on quantitative metrics may overlook qualitative, lived experiences of women in male-dominated fields like CS. Despite these efforts, HEA data continues to show persistent gender gaps in undergraduate computing programmes (Higher Education Authority (HEA), 2022), suggesting a need for more flexible, localised interventions.

Across Europe, individual HEIs have trialled various initiatives to improve gender diversity in CS. For instance, Imperial College London's Women in STEM Initiative, offers scholarships, networking opportunities, and role model engagement to inspire and support female students to pursue CS and related disciplines[4]. Likewise, the Technical University of Munich has piloted mentorship programmes, school outreach initiatives, and gender-sensitive pedagogy to foster inclusivity. These institutional efforts demonstrate the potential of targeted interventions, yet they are often

[3] https://hea.ie/policy/gender/athena-swan/
[4] https://www.imperial.ac.uk/news/212293/imperial-hosts-international-scholarships-women-stem/

critiqued for relying on short-term interventions, such as coding workshops or career fairs, that fail to sustain long-term engagement. Without sustained support structures and a deeper cultural shift within educational environments, such initiatives risk being symbolic rather than transformative.

A recurring challenge in the policy landscape is the mismatch between high-level policy aspirations and their implementation at the ground level. Standardised interventions and performance indicators, while useful for demonstrating progress, do not always address specific localised barriers faced by students and schoolteachers. This issue is particularly noticeable in CS outreach, where initiatives that generate initial interest, such as workshops and hackathons, often fail to sustain engagement or foster lasting change (Lyon and Green, 2021; Denner *et al.*, 2012)

The project documented in this thesis responds to these shortcomings. By adopting a co-design approach, it integrates local insights and stakeholder expertise into the development of a sustained outreach programme. Through a university-school partnership, this research engages schoolteachers and university management, faculty and students in designing a multi-year CS curriculum tailored to the needs, culture and resources of the local community.

This approach aligns with the goals of Ireland's STEM Education Policy Statement and global frameworks like the SDGs, but also highlights the limitations of relying solely on standardised interventions. By demonstrating how local co-design can bridge the shortcoming between policy and practice, this project contributes to a more nuanced understanding of how the gender imbalance in computer science education can be advanced through contextually responsive, collaboratively developed outreach.

1.4 Practice Context

South East Technological University (SETU) is a medium sized higher education institution (HEI) with approximately 18,000 students across five campuses in the south-east of Ireland. Officially established on May 1st 2022, through the merger of Waterford Institute of Technology (WIT) and Institute of Technology Carlow (ITC), SETU is part of Ireland's broader effort to consolidate technological HEIs into strong regional universities. The university has a well-established role in supporting education, research and industry partnerships that contribute to local and national development. My research and teaching are based at the Carlow campus within the Department of Computing, where gender representation in computer science (CS) remain an ongoing concern.

SETU has taken steps to promote gender equality, particularly through its participation in the Athena Swan Charter. Before the merger, both ITC and WIT pursued Athena Swan Institutional Bronze awards, with ITC notably becoming the first institution in the Technological Higher Education Sector to receive this recognition. In 2022, three departments within the former ITC, including the Department of Computing, secured Departmental Athena Swan Bronze Awards, demonstrating a continued commitment to addressing gender imbalances.

While these achievements represent progress, challenges remain in computing disciplines, where nationally women represent only 19-24% of students enrolled in undergraduate computing courses[5]. Despite national policies such as the STEM Education Policy Statement (2017-2026) and the introduction of Computer Science as a Leaving Certificate subject in 2018, female participation in CS remains low at both second and third levels. This reflects deeper structural and cultural barriers, necessitating interventions that extend beyond policy commitments into practice-based, context-sensitive approaches.

A key aspect of the practice context is SETU's longstanding role in developing regional partnerships. The university, and more specifically the Department of Computing, maintains strong relationships with local schools, industry partners and alumni networks, reinforcing its role as a regional hub for computing education and workforce development in the southeast of Ireland. Many computing graduates from SETU remain within the region, contributing to a sustainable local network of CS professionals. This existing ecosystem provided a strong foundation for designing and implementing a school-based intervention.

This project was able to build on these existing connections, particularly through the emerging partnership with Tullow Community School[6]. The school, located in County Carlow, had recently engaged with the Department of Computing in SETU to expand its computing education and explore new outreach initiatives. Tullow Community School is the real name of the school, and permission has been granted to name them in this thesis. Recognising this opportunity for meaningful collaboration, the project sought to build on the existing relationship between SETU

---

[5] https://hea.ie/statistics/data-for-download-and-visualisations/key-facts-figures/
[6] http://www.tullowcommunityschool.ie/

and Tullow Community School to create a co-designed intervention that directly responds to local educational needs.

Rather than taking a broad, one-off outreach approach, this project focused on a sustained school-university partnership initiative. Tullow Community School was selected as a partner institution due to its proactive approach to STEM education, its location within SETU's regional network, and its interest in enhancing computing opportunities for students. By embedding the intervention within an existing partnership, the project ensured greater alignment with local needs, institutional goals and broader policy frameworks. This approach also highlights how regional universities like SETU can act as anchor institutions facilitating sustainable, practice-driven models for improving gender imbalance in computer science.

1.5 Research Context

The underrepresentation of women in computer science (CS) education has been widely studied across disciplines such as education, gender studies and computing. Scholars argue that increasing gender diversity is not only a matter of equity but essential for fostering innovation and addressing socio-technical challenges (Blickenstaff, 2005; Wang and Degol, 2017; Sax *et al.*, 2015; Bjorn *et al.*, 2023; UNESCO, 2017). Despite decades of research and intervention efforts, progress in addressing gender disparities in computer science (CS) education remains slow, prompting calls for more context-sensitive, equity-focused approaches that target the specific barriers female students face (Blickenstaff, 2005; Barker and Aspray, 2013; Denner *et al.*, 2014).

Blickenstaff (2005) describes the "leaky pipeline" phenomenon, where women are gradually filtered out of STEM fields due to persistent structural and cultural obstacles, despite efforts to promote gender diversity. Similarly, Sax *et al.* (2015) highlight how, despite decades of outreach and policy initiatives, the proportion of women in computing has remained stubbornly low, suggesting that existing interventions have had limited success in shifting long-term participation trends. Wang and Degol (2017) further argue that gender gaps in STEM fields, including CS, stem from a combination of early socialisation, self-efficacy differences and structural barriers within educational systems.

A significant body of research highlights multiple factors contributing to gender imbalances in CS, including cultural stereotypes, institutional barriers, and confidence gaps (Fisher and Margolis, 2002; Cheryan *et al.*, 2017; Sax *et al.*, 2015). Early socialisation plays a crucial role, as computing is often perceived as a male-dominated field, discouraging female participation from an early age (Fisher and Margolis, 2002; Cheryan *et al.*, 2017). Studies show that gendered representations of computing, such as the stereotype of the solitary male coder, can negatively impact young women's career aspirations, leading to lower self-efficacy and interest in CS (Cheryan *et al.*, 2015).

Beyond social perceptions, structural and pedagogical factors also contribute to the gender gap. The lack of female role models, gendered curricula, and unsupportive classroom environments have been shown to deter female students from engaging with CS (Blickenstaff, 2005; Denner *et al.*, 2014). Research on self-efficacy and a sense of belonging suggests that students who feel socially and academically supported are more likely to persist in CS (Sax *et al.*, 2015). However, many outreach initiatives fail to address these psychological and social dimensions in a sustained manner, focusing instead on short-term interventions (Scott *et al.*, 2017).

The gender imbalance in CS education has long-term implications for industry representation. Scholars have linked low female participation in CS degrees to broader industry-wide issues, such as the lack of women in leadership roles and workplace cultures that marginalise female employees (Ashcraft *et al.*, 2016). The persistence of these disparities underscores the need for early intervention at the educational level to create a more inclusive talent pipeline. However many existing outreach efforts adopt a "one-size-fits-all" approach, such as coding workshops or career fairs, that may raise awareness but lack the long-term engagement necessary to foster confidence and sustained interest (Scott *et al.*, 2017; Bjorn *et al.*, 2023).

While the literature provides valuable insights into gender disparities in CS, shortcomings remain in how outreach initiatives can be designed to create sustainable impact. Specifically, research tends to focus on either early exposure (Denner *et al.*, 2005) or intervention-based models, but there is limited discussion on how outreach efforts can be co-designed with schools to ensure long-term engagement (Barker and Aspray, 2013; Bjorn *et al.*, 2023). Bjorn, Menendez and Borsotti (2023) argue that designing for diversity requires embedding equity-driven principles into outreach artefacts, ensuring that interventions are contextually relevant, inclusive, and adaptable.

This thesis engages with two key areas of literature: strategies to encourage female participation in CS education and computer science outreach design. These areas were chosen because addressing gender disparities in CS requires both effective interventions and a design process that ensures these interventions are contextually relevant and sustainable.

The first area examines proactive interventions, such as early exposure, short immersive programmes and specialised curricula, that have been widely used to engage female students. However, while these strategies offer valuable insights, they often do not account for how outreach efforts can be sustained or adapted to different educational environments. Without this, their impact may be short-lived or misaligned with local needs.

The second area focuses on how outreach initiatives are designed, particularly in terms of scalability, stakeholder involvement and the sharing of outreach initiative designs. Existing research on outreach design tends to focus on predefined models rather than how outreach efforts can be co-designed with local stakeholders. This shortcoming is significant because the success of an initiative depends not just on what is delivered, but how it is developed within a specific educational and cultural context.

By focusing on these two areas, this research examines how co-design can address the limitations of conventional outreach approaches. Instead of proposing a fixed outreach model, this study explores the process of developing a locally relevant initiative, how stakeholders identify problems, test solutions, and adapt their approach. This emphasis on co-design as a method, rather than the final outreach model itself is central to this study's contribution.

A more detailed review of these areas is presented in Chapter 2.

1.6 Research Questions

The research questions underpinning this study are:

> RQ1: What does the design of a context-specific outreach initiative aimed at increasing female participation in computer science higher education look like when collaboratively developed by multiple stakeholders?
>
> RQ2: What processes and interactions shape the collaborative development of a bespoke outreach initiative aimed at increasing female participation in computer science higher education?

RQ3: What do the outcomes and processes of designing a context-specific outreach initiative reveal about the potentialities and constraints within the local context for increasing female participation in computer science higher education?

These questions draw directly from the two identified areas of literature. RQ1 examines the outcome of the collaborative design process, RQ2 explores the processes and dynamics that unfold during the co-design process of a bespoke outreach programme, and RQ3 investigates the contextual enablers and barriers, contributing theoretical and practical insights to both domains.

1.7 Thesis Overview

In Chapter 2, I review the literature on strategies to encourage female participation in computer science education and computer science outreach design. In Chapter 3, I offer a rationale for the use of activity theory, expansive learning and double simulation. I describe my research design in Chapter 4 and justify the approach I have adopted. Chapter 5 presents the findings of this research study, by presenting the design of the proposed outreach initiative, describing how the proposed design emerged from the process. Chapter 6 discusses these findings in relation to the research questions and contributions to knowledge. Finally, Chapter 7 revisits the research objectives, summarises key findings, reflects on limitations and considers implications for policy, practice and future research.

Chapter 2 Literature Review

2.1 Introduction

The purpose of this chapter is to review literature to situate the work and identify the potential for contributions. Two areas of literature are reviewed to serve this purpose. These two areas of literature are; strategies to encourage female participation in computer science education and the design of computer science outreach programmes.

As discussed in Chapter 1, the research objective was broad, encompassing a wide range of factors influencing computer science education. However, through a detailed examination of the literature, the focus was refined to address specific aspects that emerged as particularly significant. This process led to the formulation of specific research questions that guide the study to ensure a targeted and impactful contribution to the field.

Section 2.2 will elucidate the process leading to the selection of two distinct areas of literature to review and provide an overview of the decision-making process that guided the identification of these areas. I will detail the search strategy for each area, the database used, search terms, inclusion criteria, and the reasoning behind these choices. The section will also describe the literature filtering process, including abstract reviews, selection criteria, and article selection for in-depth analysis.

Sections 2.3 and 2.4 will present my analysis of the literature on two areas of literature central to this study: strategies to encourage female participation in computer science education and the design of computer science outreach programmes. Each section will identify key themes, evaluate significant papers, and highlight shortcomings in the literature relevant to this study's objectives.

Section 2.5 will present the research questions, highlighting how they address notable shortcomings found in the literature. In conclusion, Section 2.6 will summarise the primary claims and shortcomings identified, articulating how my research expands upon or contests these aspects. This section will connect the methodology, research questions and theoretical framework to the reviewed literature, emphasising the new contributions to the field.

2.2 Process of Literature Selection

This section explains why I chose to review the two distinct areas of literature, strategies to encourage female participation in computer science education and the design of computer science outreach programmes.

As outlined In Chapter 1, my journey began with a personal passion to address the underrepresentation of females in computer science education (CSE), a disparity I have witnessed throughout my academic and professional experiences. Motivated by this, I embarked on a comprehensive scoping search, which revealed a wide range of topics related to gender imbalance in CSE. This initial search helped refine my focus, emphasising the importance of proactive strategies to enhance female participation in this field.

In my research, I initially explored various topics, including barriers to entry for females in CSE and the influence of mentorship programs. However, these topics did not align as closely with my goal of finding proactive and impactful measures that increase female engagement directly, rather than merely addressing existing obstacles. Through this process, I discovered that one of the most promising approaches involved the use of outreach programmes, as numerous studies emphasised their effectiveness in sparking interest and engagement among female students.

Recognising this, as discussed in Chapter 1, I decided to narrow the scope of my literature review to two key areas. The first area investigates strategies specifically aimed at increasing female participation in computer science education through proactive interventions. The second area centres around the design of computer science outreach programmes, examining how these initiatives are structured and how they contribute to broadening female interest in the field. By focusing on these two interconnected areas, I aim to understand both how to increase participation within formal education and how to reach and engage potential female entrants before they choose their study paths, thereby widening the pipeline of female participants in CSE.

2.2.1 Searching

In this section I set out my approach to searching the literature. To select relevant studies on the two areas of literature, I conducted thorough searches of research articles using the Scopus database.

To explore the first area, *strategies to encourage female participation in computer science education*, I initially experimented with various search term combinations including words like “strategies”, “encourage”, “promote”, “female”, “participation”, “underrepresentation”, “computer science”, “education”. Through this process, I realised that the term “strategies” was not frequently used in relevant research papers, even when those papers described actual methods to promote participation. I also noted “computer science” and “education” needed to be combined to yield more relevant papers. Ultimately, I opted for a more focused search using the terms *"computer science education" AND "female*"* within the article title, abstract, and keywords fields. This structured search, conducted on 10/06/24, returned 180 results published between 1996 and 2024. An outline of the search process and criteria used is presented in Table 2.1 below.

Table 2.1: Literature Review Search Overview

Strategies to encourage female participation in computer science education		**Design of computer science outreach programmes**	
Search Term	*"computer science education" AND "female*"*	**Search Terms**	*"computer science" AND "outreach" AND "design"*
Publication Years	1996 to 2024	**Publication Years**	2002 to 2024
Date of Search	10-06-2024	**Date of Search**	06-09-24
No. of Papers	180	**No. of Papers**	123
Filtered to CS only	135	**Filtered to CS only**	83
Exclusions: non-English, non-peer reviewed, duplicates, not specifically addressing female participation in CSE	25	**Exclusions:** meta studies, non-English, non-peer reviewed, duplicates, reporting on same outreach initiative by same authors.	38
Snowball	15	**Snowball**	3
Total Reviewed	**40**	**Total Reviewed**	**41**

To expand my review, I employed the snowball method by examining the references within the initially identified papers to locate additional relevant studies. This iterative process led me to discover and include 15 more papers, ultimately bringing the total number of studies evaluated for this first area of research to 40. The snowball method was particularly effective in identifying studies that were not captured in my initial database search but were still highly relevant.

After reviewing the literature on strategies to encourage female participation in computer science education, it became clear that one of the most common and effective approaches involved the use of outreach programmes. Numerous studies highlighted the significant role that outreach initiatives play in sparking interest and increasing engagement among female students. This naturally led me to investigate the broader topic of how computer science outreach programmes were designed and implemented. The decision to focus on the *design* of these outreach programmes arose from discovering in the wider computer science education literature that the way these initiatives are structured can significantly impact their success.

Consequently, I decided to focus the second part of my literature review on *the design of computer science outreach programmes*. My focus remains specifically within computer science, as outlined in Chapter 1, and is rooted within the field of Computer Science Education (CSE). This is driven by both my personal and professional experiences in computer science, as well as the unique challenges and opportunities this discipline presents. It is a well-documented global issue that computer science poses distinct barriers and opportunities for female students, which differ from those in broader STEM fields. This targeted approach within CSE not only helped me navigate the extensive body of literature but also allowed me to engage more deeper into the specifics of effective outreach strategies tailored to computer science.

To explore the second area, *the design of computer science outreach programmes*, I began by conducting a broad search in the Scopus database using the keywords ”Computer Science AND outreach”. This initial search yielded 468 papers, and it became clear that the majority of these papers failed to discuss the design of outreach programmes. Thus, I structured my search within the article title, abstract and keywords fields using the search string: *"computer science" AND "outreach" AND "design"*. This search, conducted on 06/09/24, returned 123 results dated between 2002 and 2024. An outline of the search process and criteria used is presented in Table 2.1.

Results from searches of the two research areas were drawn from peer-reviewed journals, academic texts and conference proceedings, whose abstracts I exported into separate spreadsheets. I then filtered and analysed each area as described below, referring to the snowball method mentioned earlier as part of the strategy used to expand the body of literature reviewed.

2.2.2 Filtering

The goal of the filtering process was to eliminate papers that were not relevant to the research and narrow down the number of papers for consideration.

For my review of *strategies to encourage female participation in computer science education*, I focused specifically on papers related to computer science, excluding broader fields such as information technology or other STEM areas. From the initial 180 papers returned, as detailed in section 2.2.1, many were more relevant to engineering or other non-computer science disciplines. To refine my results and ensure relevance to computer science, I filtered the Scopus search to the subject area of “Computer Science”, which reduced the number of papers to 135.

I further narrowed this selection by focusing on studies that centred on education and female students and were written in English. I excluded duplicates, non-peer reviewed papers, non-English papers, and those not specifically addressing female participation in computer science education. After reviewing the abstracts of the remaining papers, I discarded those that were not directly relevant, reducing the number to 25.

As mentioned in Section 2.2.1, I employed the snowball method as a supplementary approach to expand my review. By examining references within these papers, I identified and included 15 additional relevant studies, bringing the total number of studies evaluated for this first area of research to 40.

For my review of *the design of computer science outreach programmes,* I specifically sought papers that examined the design aspects of computer science outreach programmes. From the initial 123 papers returned from my search, as detailed in section 2.2.1, I again found that many were more relevant to fields such as engineering. To refine the results and ensure they were pertinent to computer science, I filtered the Scopus search results to the subject area of “Computer Science”, which reduced the list to 83 relevant results.

I aimed to identify studies that specifically addressed the design of computer science outreach programmes. Thus, I excluded papers that were meta studies or that covered multiple outreach interventions, as well as those focused on outreach initiatives for other STEM fields like science or engineering. Additionally, I discarded non-English papers, non-peer reviewed studies, and duplicates, including papers reporting on the same outreach initiative by the same authors.

After applying these filters, I reviewed the abstracts of the remaining papers and removed those that were not directly relevant to my focus. This process further narrowed the number of papers to 38. Similar to the approach used in the first area of research, I employed the snowball method to find additional relevant studies that met my criteria, leading to the inclusion of 3 more papers and resulting in a total of 41 studies for this area of research.

2.2.3 Analysing the literature

After selecting and filtering relevant papers, I analysed a total of 40 papers for the first area, strategies to encourage female participation in computer science education and a total of 41 papers for the second area, the design of computer science outreach programmes. To provide a comprehensive understanding of the literature, my review is organised into two sections, each addressing key themes identified through the analysis.

The first section, section 2.3, focusing on *strategies to encourage female participation in computer science education,* includes three central themes:

i. Early exposure
ii. Short immersive interventions
iii. Specialised curriculum approaches

The second section, section 2.4, addresses *the design of computer science outreach programmes* and is organised around the following themes:

i. Scalability
ii. Sharing of outreach initiative design
iii. Outreach designer expertise

Several other themes were identified during the review process, but I decided to exclude them from my analysis as they were not directly relevant to the focus of my research. Examples include barriers to entry such as stereotypes and females' sense of belonging. While these topics are important, they were not included in this study because the primary aim is to concentrate on proactive measures and programme designs that directly address and enhance female participation. For instance, while understanding barriers like stereotypes is crucial, my focus is on identifying actionable strategies and effective designs that actively foster engagement and support for female students in computer science.

2.3 Strategies to Encourage Female Participation in Computer Science Education

In this first area of the literature, I review the literature on strategies to encourage female participation in computer science education. The three themes I will focus on are: (i) early exposure, (ii) short immersive interventions and (iii) specialised curriculum approaches. Each theme encompasses a range of strategies employed to overcome the barriers faced by females in pursuing computer science. Understanding these strategies is essential for identifying effective approaches and the root causes of the gender disparity that remains today.

2.3.1 Early exposure

One common theme that emerges from the literature on strategies to encourage female participation in computer science is *early exposure.* Numerous studies advocate for introducing girls to computer science at a young age, or as early as possible (Gürer and Camp, 2002), typically during primary or secondary education, to positively influence their long-term engagement in the field. For instance, French & Crouse (2018) argue that "early interventions" are essential for building a foundation of interest and skills in computer science. They contend that a lack of early exposure constitutes a significant barrier, and addressing it increases the likelihood of sustained interest in the subject. The literature consistently supports the view that early exposure plays a critical role in shaping attitudes, foundational skills and aspirations toward computer science.

A key consideration highlighted by several studies is the value of *challenge-based learning* as an effective approach within early exposure initiatives to create interest. Research suggests that introducing young female students to computer science through intellectually stimulating but achievable tasks at an early age increases their engagement and curiosity about the field. Programmes designed for primary or secondary education that incorporate problem-solving challenges or real-world applications, such as game development or app creation, have been shown to be particularly effective in capturing and maintaining girls' interest. This method of early exposure not only demystifies coding but also aligns with the intrinsic motivation of many young learners to tackle meaningful, real-world problems (Denner *et al.*, 2005). By engaging students early through challenges, the learning process becomes more accessible and motivating, laying a solid foundation for sustained interest and future participation in computer science. Şahin Timar

& Mısırlı (2023) advocate for "creating interest by challenges" as a key strategy, especially when these tasks are aligned with the ways in which young students naturally interact with technology.

Another argument in the literature centres around the need to present computer science as an *enjoyable* and *creative* pursuit. Some authors, such as Yates & Plagnol (2022), suggest that early exposure not only helps participants view computer science as a viable academic option but also demonstrates that coding can be fun and enjoyable. This contrasts with traditional perceptions of computer science as a dry, solitary activity, within a male-dominated domain (Margolis and Fisher, 2003), which can deter girls. Several studies recommend outreach programmes and classroom activities that actively showcase the fun and collaborative aspects of coding. Incorporating elements like game design, storytelling, or art into programming lessons helps reframe computer science as a creative and interactive field, which can be particularly effective in challenging the "tech geek" stereotype (Anderson *et al.*, 2008) and showing girls that the discipline can align with various interests.

Another argument in the literature advocates for integrating computer science concepts into existing school curricula through *computational thinking (CT)*. CT is a problem-solving process foundational to computer science, and several studies emphasise that introducing these skills early, particularly in middle school, can serve as a crucial form of early exposure (Beason *et al.*, 2020). Embedding CT in familiar subjects like mathematics or science allows girls to encounter computer science concepts naturally, building confidence and interest in a low-pressure environment. This early integration helps demystify the subject, showing its relevance and accessibility, which increases likelihood of further engagement (Settle et al., 2012). "*The work done at the Lab Schools has demonstrated how computational thinking can be integrated into middle- and high-school courses. Examples of computational thinking in non computer-science disciplines are particularly important for progress in this area*."

However, despite the consensus on the benefits of early exposure, a notable shortcoming in the literature is the lack of guidance on how to sustain the engagement initiated by these programmes. While early exposure programmes can spark initial interest in computer science, it often neglects the challenge of maintaining that interest as girls transition to more advanced stages of education. During this time, they may face additional barriers, such as peer influence, societal expectations, and a lack of ongoing mentorship, which can lead to a decline in their enthusiasm for the field. The literature is often unclear about how these early experiences shape decisions regarding the pursuit of computer science at the senior level of secondary school or in higher education, and what additional supports might be necessary to sustain engagement. This shortcoming highlights the need for further research focused on transitioning early experiences into long-term participation, as well as investigating whether supplementary mechanisms are needed to maintain momentum. By addressing these aspects, future studies could contribute to creating a more comprehensive framework for ensuring that early exposure programmes result in lasting engagement rather than remaining isolated experiences.

2.3.2 Short immersive interventions

Another common theme that emerges from the literature on strategies to encourage female participation in computer science education is the use of *short immersive interventions*. The literature highlights interventions designed to create a strong, immediate impact at engaging students. These experiences often take the form of workshops, coding competitions, summer camps or hackathons, and are designed to provide concentrated bursts of exposure and hands-on experience within a limited timeframe, ranging from just a few hours to several days. Unlike long-term programmes, these interventions aim to spark immediate interest by delivering targeted training, building confidence, and offering practical achievements in a short period. For instance, Eidelman et al. (2011) argue that even a short 2-hour visit to a hi-tech company can change students' perceptions of what computer science is and increases their interest in the subject.

One consideration highlighted in the literature is the effect that *well-structured* programmes can have on interest in computer science. Well-structured interventions typically include clear objectives, engaging activities, and immediate feedback mechanisms, ensuring that participants have a meaningful and enjoyable experience. These programmes often incorporate hands-on projects, interactive discussions, and opportunities for personal reflection which help participants grasp complex concepts in an accessible way. Short-term initiatives often capitalise on the idea that a focused burst of engagement, such as a day-long workshop or a weekend hackathon, can have a strong motivational impact. Research indicates that these experiences are particularly effective at demystifying computer science for girls who may have little to no prior exposure. The literature advocates for a well-structured intervention, attributing this to the success of their initiatives (Rosson *et al.*, 2010; Kaval *et al.*, 2024). "*The success of the workshops can be attributed at least in part to the scaffolding built into the projects*". By rapidly building confidence and demonstrating immediate results, such as creating a website or learning a programming language, these events can create a sense of accomplishment that longer, drawn-out programmes may struggle to achieve. The literature suggests that this sense of immediate success is critical in bolstering their confidence to pursue computer science and overcoming initial fears about the sense of belonging amongst their peers (Kaval *et al.*, 2024).

Another important point is the *collaborative, social aspect* of these short-term initiatives. Studies argue that many girls are more likely to engage in computer science when the environment is framed as a group activity (Margolis and Fisher, 2003) rather than a solitary one. Hackathons, for instance, emphasise teamwork and problem-solving in small groups (Denner *et al.*, 2005), fostering a sense of community and shared achievement. Authors suggest that this collaborative environment can alleviate feelings of isolation and anxiety that often accompany entering a male-dominated field. Furthermore, collaboration allows participants to learn from one another, share diverse perspectives, and build lasting connections that can inspire continued interest in computer science. This peer interaction plays a crucial role in challenging the perception of coding as an isolating activity. Additionally, these programs frequently feature mentorship from female role models in the industry, providing girls with real-world examples of women excelling in the field (Margolis and Fisher, 2003), which helps to further dismantle gender stereotypes.

A primary strength of the literature on short immersive interventions is its recognition of their ability to provide high impact, engaging experiences that can quickly spark interest in computer science. These studies highlight how such interventions can reach a large number of participants in a short time, creating opportunities for individuals to showcase their skills and gain confidence. However, the literature also reveals notable weaknesses. While short-term interventions are effective in generating immediate enthusiasm, they often struggle to maintain momentum once the event concludes. The limited duration of these interventions can hinder in-depth skill development and sustained behaviour change, limiting their long-term impact. Furthermore, the literature frequently overlooks deeper, systemic issues, such as gender biases and the lack of role models, which can undermine the potential benefits of these initiatives. The interest generated by these one-off events may not be sustained without follow-up activities, leading to a risk that participants view the experience as isolated rather than the beginning of a continued journey in the field. This shortcoming in the literature suggests a critical need for further exploration into the mechanisms required to support ongoing engagement and development beyond these initial interventions.

2.3.3 Specialised curriculum approaches

Another prominent theme in the literature on strategies on encouraging female participation in computer science is the use of *specialised curriculum approaches*. The literature reveals that interventions, rather than providing a wide, all-encompassing introduction to computer science, concentrate closely on one or a limited number of specialised topics, including web development, robotics, or game design. The idea behind these focused approaches is that teachers can encourage students' greater involvement and interest in computer science by focusing on subjects that may be especially fascinating or pertinent to them (Roscoe *et al.*, 2014; Sharma *et al.*, 2021; Jamshidi *et al.*, 2024), especially girls.

One consideration in the literature is *interest-driven learning*. Research shows that areas like website development, art and game design frequently resonate more with students and provide them a sense of immediate relevance and application. For instance, the goal of a project by Webb et al. (2012), was to increase opportunities for computer science education in public schools by motivating and educating students about computer science through game design. These focused techniques provide an accessible entry point into computer science for female students who may not have been historically exposed to coding or other technical professions. These curricula are designed to dispel the myth that computer science is solely about writing code by emphasising creative or practical components like creating a robot or game, which increases the subject's appeal. The literature argues that utilising games and creative projects helps in making computer science more appealing and less intimidating, thus attracting more female students. Advocates of specialised curriculum argue that adopting and implementing this strategy can lead to tangible improvements in female representation in computer science.

Some studies argue that using *hands-on, project-based learning* in areas that are familiar and exciting can make computer science more accessible. For example, by using music to teach programming might attract students who are passionate about music to computer science. These interventions allow for deep exploration and skill development in specific areas of interest. Other articles advocate game-based learning as engaging for many students (Sharma *et al.*, 2021; Mladenović *et al.*, 2016; Roscoe *et al.*, 2014; Buffum *et al.*, 2015). These strategies may not appeal to all, particularly those who do not enjoy music or gaming. There is a risk of reinforcing stereotypes if games are not carefully designed to be gender-neutral or inclusive. The effectiveness of these interventions in improving long-term interest and skill acquisition is still under debate. Specialised curriculum face significant challenges in effectively engaging participants and developing new skills, as highlighted in a paper reporting on teaching computational thinking by playing games and building robots (Roscoe *et al.*, 2014). They highlight that outreach designers can readily identity topics of potential interest, but translating the interest into meaningful engagement and skill acquisition is complex.

However, what seems lacking is an emphasis on the potential limitations of these specialised curricula in providing a comprehensive understanding of computer science. Authors Şahin Timar & Mısırlı (2023) attributed that increased awareness of the diverse fields within informatics can help female students to find an area they resonate with and feel a sense of belonging in. "*Inadequate familiarity with the field of informatics represents another contributing factor to the observed dearth of female interest in this domain. Often, girls associate informatics exclusively with coding, failing to recognize the broad range of areas within the field, encompassing not only coding but also design and other domains. Greater awareness of the diverse areas within informatics can enable female students to locate a sphere in which they can identify with and belong to*." While specialised topics can spark interest, many studies fail to address whether students are developing the foundational skills necessary to progress within the broader field. This approach of specialised curriculum approaches does not provide a comprehensive overview of computer science as a whole. While effective for those with an interest in the specific topic, they may not appeal to all students, limiting their overall reach and impact. More research is needed to understand how these targeted approaches can be integrated with broader computer science education.

2.3.4 Summary

The literature highlights a range of strategies aimed at addressing the gender disparity in computer science education, with varying degrees of consensus around their effectiveness. One consideration is early exposure (2.3.1), where there is strong agreement that introducing girls to computer science at a young age is essential for fostering long-term interest in the field. Many studies advocate for challenge-based and creative approaches to early exposure, however, there is less clarity on how to sustain engagement over time, particularly as students encounter additional barriers in later educational stages. This suggests that early exposure alone may not be sufficient without ongoing support and reinforcement.

In contrast, short immersive interventions (2.3.3), such as workshops and hackathons, are recognised for their ability to generate immediate interest and build confidence within a condensed timeframe. These interventions often provide hands-on experiences that demystify coding and computer science for females, and the collaborative, social aspect is frequently cited as key to their success. However, the literature points to a significant shortcoming: while these short-terms programmes can ignite initial enthusiasm, they lack follow-up mechanisms, raising concerns about whether they lead to sustained interest or deeper skill development.

The literature on specialised curriculum approaches (2.3.3) presents a more focused strategy, with targeted topics like website development and game design offering accessible entry points for females. These specialised programmes resonate with students' interests and provide tangible outcomes, yet there is debate over whether they offer a broad enough foundation in computer science. Many studies indicate that while these specialised curricula equip students with the essential knowledge and skills, they must also ensure that students are prepared to make informed decisions about pursuing further education and careers in computer science.

Together, the literature suggests that we must engage students early, implement sustainable initiatives, and capture their interest through creative and relevant approaches. One limitation across these strategies is the lack of research into how different approaches might be integrated into a multi-faceted approach to support girls over the long term. While each strategy has merit in generating initial engagement, the literature reveals a significant shortcoming in understanding how these approaches can be integrated into a cohesive framework that fosters continuous learning opportunities for girls in computer science. This highlights the need for further research to explore effective combinations of strategies that can support sustained engagement and development over time.

2.4 Computer Science Outreach Design

In this section, I review the literature on the design of computer science outreach programmes. The three themes I will focus on are: (i) scalability, (ii) sharing of outreach initiative design, and (iii) outreach designer expertise. Each theme highlights key aspects of how outreach programmes are designed. Understanding how outreach initiatives are designed is crucial to addressing shortcomings that may influence the effectiveness and inclusivity of these programmes.

2.4.1 Scalability

One common theme that emerges from the literature on the design of computer science outreach programmes is *scalability*. Scalability refers to the capacity of outreach initiatives to expand their reach and impact across multiple settings without compromising quality. Numerous studies advocate for outreach initiatives that are not only effective within a specific context but also adaptable and replicable across diverse educational environments (Craig and Horton, 2009; Lawlor *et al.*, 2020). For example, Denning et al. (2013), distributed 800 copies of their Control-Alt-Hack card game to 150 educators and gathered feedback from 22 of them, who used the game with over 450 students in both classroom and non-classroom settings, thus demonstrating how strategic outreach efforts can be designed to maximise participation across diverse groups. In their study, Eidelman et al (2011) said "*A key principle in designing this program was to reach as many students as possible, in the given time restrictions, and make a significant impact*".

While scalability is often a core objective of outreach initiatives, the literature reveals a tension between achieving broad reach and adapting to specific local contexts. Several authors, such as Gottipati & Shankararaman (2018), describe their outreach initiative which they designed for a specific target audience, junior colleges. This suggests that they prioritise immediate impact with that target audience over broader scalability. However, these authors often conclude by sharing resources and experiences to assist others in replicating their efforts. Similarly, Chen et al. (2019) and Cleary et al. (2015) provide valuable resources, including links to websites containing source code, documentation and camp materials, to facilitate replication by other educators. A concern lies in just how much these resources are actually adapted or tailored to fit different local settings and community needs or if they are replicated exactly without much consideration of these things.

A key consideration in achieving scalability is the development of *standardised frameworks* that facilitate widespread implementation. Several studies promote the creation of universal designs that can be easily adapted and adopted across diverse regions and educational institutions (Cateté *et al.*, 2014; Hulsey *et al.*, 2014). Cateté et al., for example, offer a comprehensive framework for conducting computing outreach activities, making their resources widely accessible to others wishing to implement similar programmes. Hulsey et al. echo this approach, stating "*We will be posting our challenges and other materials online for other groups who might be interested in using them for their own programs*". By sharing their teaching materials online, they aim to encourage other groups to replicate their programme, thus promoting scalability through shared resources. However, while these frameworks enable replication, they may not fully account for the unique cultural, economic, and institutional factors that can shape the success of outreach efforts in different regions. Sauppé et al. (2015) similarly illustrate this tension in their work on social robotics outreach. Although they present their programme as adaptable for different audiences and suggest ways it could be modified for other computer science topics, they acknowledge that effectiveness still depends on the ability to customise these lessons based on local resources and cultural dynamics.

The literature suggests that while standardisation can support scalability, it may introduce limitations. Lang et al. (2015) reflect on their experiences with the Digital Divas Club, a curriculum-based programme delivered in Australian schools to stimulate junior and middle school girls' interest in computing courses and careers. Despite creating a well-developed curriculum in collaboration with teachers, the programme's outcomes varied significantly based on local factors such as school culture and teacher engagement levels. The authors argue that while their standardised and scalable approach enabled broad participation, it also underscored the need for deeper contextual understanding to ensure the programme's relevance and impact across diverse school environments. This highlights a critical shortcoming in the literature, while standardised models are often presented as universally applicable, they may overlook local cultural contexts and institutional dynamics which in turn can affect participation and impact.

Despite the emphasis on scalability as a positive objective in outreach programmed design, there remains a notable shortcoming in how these models address the specific needs of varied educational and cultural contexts. While scalable and replicable frameworks aim to expand impact, they often promote a standardised, one-size-fits-all approach that may detract from the engagement required in to varying local contexts. This can lead to programmes that lack the necessary depth and flexibility required to resonate with students from diverse backgrounds or in schools with different resources. For example, what works well in urban schools may not translate seamlessly to rural or underserved communities, where resources, access to technology, and cultural attitudes toward computer science may differ significantly. The literature suggests that, to truly foster engagement across diverse populations, outreach initiatives may need to prioritise context-specific designs that go beyond the limitations of broad, scalable models. Addressing the distinct challenges faced by various subgroups, particularly those from diverse racial, cultural or socio-economic backgrounds, requires a different approach than standardised frameworks typically provide.

2.4.2 Sharing of outreach initiative design

One theme that arises in the literature about computer science outreach initiatives is the *sharing of outreach initiative design*. For instance, Sauppé et al. (2015) offer an account of their outreach initiative involving social robotics, with a particular focus on the logistical aspects, programming environments and exercises conducted in their programme. "*We present the design of an outreach course aimed at simultaneously engaging young and senior students while encouraging enthusiasm for science and technology by providing instruction in computer science and social robotics.*"

The literature is often dominated by studies that emphasise *outcome-focused narrative*, with a predominant focus on the structure of the initiatives rather than on the design processes themselves. For instance, Lau et al. (2009) briefly mention the program design of their initiative, which incorporated fashion and design elements into programming courses, but their primary focus remains on the outcomes rather than the steps and considerations behind these choices. Gottipati & Shankararaman (2018) provide a more comprehensive account by detailing the gamified design of their outreach camp in Singapore, highlighting the gaming mechanics and stages implemented. However, even this study centres on what was executed rather than offering a transparent view of the decision-making, iterations, or challenges encountered during the actual design process. This pattern is consistent across other studies, such as those by Huggard & Mc Goldrick (2006) and Lawlor et al. (2020), who focus primarily on strategic approaches and logistical setups rather than delving into the deeper design aspects and rationale behind their outreach initiative.

The literature frequently shares quantitative details such as the number of courses offered, participant engagement levels, and types of technologies or activities used. While several studies, including those by Chen et al. (2019) and Cleary et al. (2015), make efforts to share resources such as programming code and instructional materials to aid replication, this emphasis provides less attention to the design process itself. These resources are valuable, but they rarely include insights into the iterative stages, design trade-offs and contextual decisions that led to their creation. For example, Denning et al. (2013) provide a high-level view of their game development process but do not elaborate on the iterative steps and specific design decisions made throughout their initiative. Gannod et al. (2015) who emphasise user-centred design in their summer camp programme, they also provide limited elaboration on the considerations and iterations made during development. This lack of transparency in the design process makes it difficult to comprehend the trade-offs and adjustments required to achieve the final program structure for its intended target audience, hindering a deeper understanding of the design process.

The absence of detailed design documentation leaves a knowledge shortcoming in the field, potentially making it challenging for others to understand the reasoning behind certain decisions or to anticipate the challenges they might face when developing their own programmes. The lack of depth in documenting and sharing these iterative processes and challenges represents a critical shortcoming in the literature. It highlights the need for a more detailed and transparent narrative around the decision-making processes behind outreach program design, which could provide valuable guidance for educators or institutions developing similar initiatives. Moreover, without such insights, outreach designers may struggle to anticipate or navigate similar challenges in their own contexts, reducing the overall effectiveness and adaptability of these programs. We don't learn about the reasons behind why the final solutions was implemented, or about the components considered and why they were omitted from the solution. They may not realise that the design challenges, decisions, and iterative adjustments are just as valuable as the completed design, especially for others looking to design or implement their own outreach interventions.

2.4.3 Outreach designer expertise

Another theme that emerged from the literature on computer science outreach design is *outreach designer expertise*. The design and development of outreach initiatives are often led by small, homogeneous groups of individuals with similar backgrounds, needs, and authority, such as academics, PhD students, industry professionals, or representatives from non-profit organisations professionals (Eidelman *et al.*, 2011). This expertise is primarily domain-specific, typically focusing on technical and academic aspects rather than incorporating a broader range of perspectives.

Several studies, such as those by Huggard & Mc Goldrick (2006), show that university-led initiatives often prioritise strategic, *faculty-driven approaches* without actively seeking input from the communities they aim to serve. These programmes, despite their technical soundness, may struggle to gain cultural relevance, local buy-in, or long-term sustainability. The homogeneity of design teams, typically composed of university faculty or technology experts, may lead to initiatives that, while technically competent, lack the diversity of perspectives needed to connect with the target audience. The continued reliance on small, specialised groups of designers raises concerns about whether these outreach efforts align with the needs and priorities of local communities.

Many studies such as those by Veron et al. (2023) and Isvik et al. (2020) outline the design and evaluation of their outreach programmes without mentioning any input from key local stakeholders such local teachers, students, or parents in the programme's conception. This omission suggests that outreach initiatives are frequently designed by university experts (often the paper's authors) with limited or no engagement from the communities these programmes aim to serve. Similarly, the study by Lau et al. (2009) describes the development of a programmes designed for middle school students but does not discuss whether students or educators were consulted during the design phase.

Denning et al. (2013) provide an example where the design process was guided solely by the designers' expertise in computer security, with minimal input from game mechanics experts, despite the development being a tabletop card game. This illustrates common limitation where programme designers rely primarily on their own domain expertise without consulting external sources that could provide more relevant insights, such as input from educators, students or community members. By contrast while Gottipati & Shankararaman (2018) conducted surveys to gauge student awareness when designing their outreach camp, they did not engage students, parents, or other local educators in the design process, thereby missing an opportunity to incorporate diverse perspectives and insights.

One strand of work emphasises the expertise of researchers who have been active in the field of women in computing, both nationally and internationally, and who have long been concerned with the limited effects of intervention programs. For instance, Lang et al. (2015) examined their Digital Divas Club, an outreach initiative designed to stimulate junior and middle school girls' interest in computing. The authors, who had extensive experience in the field, believed that their collective knowledge was sufficient to design an effective curriculum-based programme. Despite delivering a positive and multi-layered computing experience, the programme ultimately did not succeed in influencing participants' desire to pursue computing careers. Lang et al. (2015) concluded, "*We believed our combined experience provided us with a strong understanding of the problem and its multi-layered aspects.*" This suggests that while domain expertise is valuable, it may not be sufficient on its own to ensure the success of outreach programs.

The literature shows a shortcoming in documenting the effects of incorporating broader expertise into the design process. Studies often fail to investigate how collaborative or community-driven approaches might influence the outcomes and sustainability of outreach programs. Given the lack of consensus and documentation on the role of diverse expertise in outreach program design, further research exploring inclusive design processes is needed. It would be valuable to investigate how an inclusive approach, including a range of perspectives, particularly from local educators, parents, and students, could enhance the cultural relevance and effectiveness of these initiatives.

2.4.4 Summary

The literature on the design of computer science outreach initiatives explores several key aspects that shape their development and effectiveness. One central theme is scalability (2.4.1), where there is consensus that outreach programmes must be designed to expand their reach across diverse educational settings without compromising quality. Many studies advocate for standardised frameworks that allow for broad replication, but there is a noted tension between achieving widespread scalability and adapting to specific local contexts. This suggests that while scalable models can effectively increase outreach, they often fail to account for cultural and socio-economic differences that influence programme success, making them less effective for diverse or underserved communities.

In contrast, the theme of sharing outreach initiative design (2.4.2) highlights the importance of collaboration and resource dissemination, with several studies offering valuable programming materials and logistical guides to facilitate replication. While this transparency is beneficial, the literature predominantly focuses on outcomes rather than the decision-making and design processes behind these initiatives This lack of detailed documentation about the challenges and adaptions made during the design phase limits other's ability to replicate and adapt these programmes effectively, potentially hindering innovation and contextual adaption.

The third theme, outreach designer expertise (2.4.3), reveals that the programmes are often designed by small, homogenous groups of technical experts, typically from universities. While their domain expertise is valuable, the absence of broader community input, including voices from local educators or students can limit the cultural relevance and long-term sustainability of these initiatives. The literature shows that although technical accuracy and knowledge is important, engaging a diverse set of stakeholders is essential to create programmes that resonate with and benefit the communities they aim to serve.

Overall, the literature provides a foundation for understanding the design of outreach initiatives but highlights critical shortcomings. While efforts to create scalable and shareable models are valuable, they often overlook the importance of local context and stakeholder involvement. To enhance the relevance and impact of computer science outreach programmes, further research is needed to explore inclusive, community-driven design approaches that integrate a diversity of perspectives. This would help bridge the shortcoming between scalability and cultural adaptability, ensuring these programmes are both far-reaching and deeply effective for diverse populations.

2.5 Research Questions

The literature on strategies to encourage female participation in computer science education and the design of computer science outreach programmes highlights the need for targeted, context-sensitive strategies. While approaches like early exposure and short immersive interventions have shown some success (sections 2.3.1 and 2.3.2), they often lack local adaption and support, which in turn limits their long-term impact. Outreach programmes typically designed by homogeneous groups, as noted in the literature (sections 2.4.1 and 2.4.3), frequently fail to address cultural and socio-economic differences, limiting their effectiveness for diverse communities.

To address these shortcomings, I argue that a more locally engaged approach is needed, involving diverse stakeholders in a co-design process. This method aims to create a bespoke context-specific outreach initiative that better reflects local needs, resources, and values. By documenting this collaborative development process, my project seeks to document this process, providing valuable insights into how such an initiative is developed.

My first research question is therefore:

RQ1: *What does the design of a context-specific outreach initiative aimed at increasing female participation in computer science higher education look like when collaboratively developed by multiple stakeholders?*

This question seeks to explore and illustrate the proposed product that emerges from a collaborative design process involving diverse stakeholders, such as management, educators and students. By examining the outcome of this co-design process, the research aims to identify the key elements, features, and strategies that stakeholders collectively deem effective for increasing female participation in computer science in a local context. The focus is on capturing the specific design choices made when designing an outreach initiative, highlighting how these choices reflect the unique needs, values and resources of the specific setting. This research aims to shed light on what a locally relevant, bespoke programme might entail when developed through and inclusive and collaborative approach.

My second research question focuses on understanding the steps and dynamics that contribute to the emergence of the design:

> RQ2: *What processes and interactions shape the collaborative development of a bespoke outreach initiative aimed at increasing female participation in computer science higher education?*

This question focuses on uncovering the processes and dynamics that unfold during the co-design process of a tailored outreach programme. It investigates how stakeholders interact, negotiate, and make decisions throughout the collaborative development process. By examining the steps taken and the engagement strategies employed, the research aims to understand how the various perspectives and expertise are integrated, what challenges and opportunities emerge, and how they are collectively addressed. This research provides insight into the ways in which stakeholders work together to create a programme that aligns with local values and needs, emphasising the importance of collaboration and participatory design in crafting context-specific solutions.

Finally, my third research question looks at the opportunities and limitations within the local environment for implementing such initiatives:

> RQ3: *What do the outcomes and processes of designing a context-specific outreach initiative reveal about the potentialities and constraints within the local context for increasing female participation in computer science higher education?*

This question explores the broader implications of both the design process and its outcome. It examines what the collaborative development and the resulting outreach initiative reveal about the opportunities and limitations present in the local environment. By analysing the interaction between the programme's design and the local context, the research seeks to identify enabling factors, such as resources, institutional support, and cultural attitudes, as well as constraints. including barriers, structural limitations, and other local challenges. This question aims to provide an understanding of how the local context influences the feasibility and effectiveness of outreach efforts aimed at increasing female participation in computer science, thereby offering insights into the conditions necessary for the success of such initiatives.

The analysis of the literature highlights several critical insights. First, it emphasises the importance of adopting a collaborative, context-specific approach to outreach initiatives, moving beyond generic, one-size-fits-all strategies to effectively address the distinct needs and circumstances of female students in diverse local settings. Second, it underscores the value of involving a broad range of stakeholders in the co-design process, such as university and school educators, management and students, to ensure that the outreach programmes are not only inclusive and relevant but also responsive to local challenges and resources. Finally, the literature reveals that understanding the specific dynamics, interactions and strategies that shape the during the design process, along with the potentialities and constraints within the local context, is crucial for designing effective and sustainable initiatives. Such an understanding enables future outreach efforts to be better tailored to the specific context they aim to serve, thereby enhancing their impact and success.

2.6 Conclusion

In this chapter, I have analysed the literature on the strategies to encourage female participation in computer science education and the design of computer science outreach programmes. I have highlighted key themes including the importance of early exposure, the role of challenge-based learning, and the need for context-sensitive designs. These themes reveal a landscape in which effective outreach often depends on targeted, inclusive approaches that actively engage young women and highlight computer science as an accessible and dynamic field. Through this analysis, I have identified key areas where my research can contribute to ongoing discussions, particularly in terms of designing context-specific outreach programmes developed collaboratively with diverse stakeholders.

I have also highlighted shortcomings in the literature, particularly the tendency of many outreach interventions to be either too descriptive of existing barriers or overly prescriptive, with one-size-fits-all solutions that overlook the unique cultural and institutional factors influencing engagement across different communities. These outreach programmes are often designed by a small, homogeneous group, leading to a lack of adaptation for diverse contexts and a limited understanding of how local conditions impact female students' experiences in computer science education. This literature review has been instrumental in shaping and refining my research questions, focusing my project on the collaborative, context-specific design process and the role of local stakeholders in creating meaningful outreach initiatives.

In the next chapter, I will set out the theoretical framework for my research, which will underpin the analysis of these themes and guide my exploration of the co-design process within local education contexts.

Chapter 3 Theoretical Framework

3.1 Introduction

This chapter sets out the core concepts that are used in the design, execution, and analysis of this project. I will provide an outline of these theoretical concepts that will be applied throughout the rest of the thesis and describe why I have chosen them in addition to how they will be used by providing examples of their use relevant to this project.

I begin by presenting my research underpinnings in section 3.2, where I describe my ontological position, my understanding of reality and how it can be changed. In section 3.3. I discuss *Activity Theory* which frames the overall project and is used by participants to analyse their own practices. I also use Activity Theory to analyse the research-intervention that I will design with participants. *Expansive Learning* is discussed in section 3.4, which guides the overall strategy of the research-intervention and following this in section 3.5 is *Double-Stimulation* which serves as a mechanism for designing and implementing the particular tasks undertaken by participants within the research-intervention. The process of expansive learning is applied through a formative intervention methodology known as the Change Laboratory, described in the Research Design chapter. The theoretical underpinnings of *Formative Interventions,* of which the Change Laboratory is a specific type, are discussed in section 3.6. The chapter then closes with a summary of my project's theoretical framework, leading into the research design.

As I elaborated in Chapter 1, the purpose of this project is to focus on changing actual activity systems. The approach to be used in this study involves bringing the theoretical frameworks together in a systematic way in order to learn how to change existing student recruitment and develop new models of activity through the co-design of a new outreach solution by multiple participants.

3.2 Research Underpinnings

My ontological position and epistemological assumptions which underpin my research are grounded in dialectical materialism, the belief that the world is material but constantly changing (Engels, 1877/1976). It is my belief that a reality exists out there that we engage with, that we can experience, study, and strive to understand. Our experience comes from interacting with this dynamic reality, and crucially, we can participate in its change by intervening with it, a perspective that resonates strongly with my professional and research context (as introduced in Section 1.5).

My position aligns with the work of Marx, who asserted that it is only by trying to change the world that we can truly understand it. Mere contemplation alone is insufficient, it is through practical engagement that hidden structures and contradictions become visible. As Marx famously claimed “the philosophers have only *interpreted* the world in various ways; the point is to *change* it” (Marx, 1976, p. 3). In my own professional practice, even before the initiation of this research project, I found that it was by directly engaging with the challenges faced by students and schools – rather than merely observing them - that I began to recognise the structural barriers to equitable participation in computing. These formative experiences, outlined in Section 1.4, shaped my belief in the importance of collaborative, interventionist approaches and motivated my decision to undertake a research-intervention focused on gender balance in computer science.

Bligh and Flood (2015) describe Marx's dialectical-materialist position as a belief that “the material world exists prior to human consciousness of it (materialism), and that increasing our knowledge of the world means understanding how apparently disparate phenomena are, in fact, deeply connected and constantly developing (dialectics)” (p. 3). Gaining knowledge in this way means more than simply *thinking* - it requires *intervention*. As discussed in Section 1.2, my professional experience revealed that existing outreach activities were not effectively addressing gender imbalances, motivating me to engage stakeholders actively to co-design a new initiative rather than simply analysing existing structures.

For Marx, humans undertake activity because of problems and circumstances that materially confront them. In doing so, they change both the reality that confronts them and their own consciousness of that reality. Highlighted by Blunden (2010), Marx did not offer a precise definition of the concept of activity, which he referred to as Tätigkeit, but activity is understood here as “the *relationship between* the ‘subjective’ and ‘objective’ within a single reality” (Bligh and Flood, 2017, emphasis in original). The specific problems identified through the partnership between SETU and Tullow Community School (Section 1.4), such as short-term interventions failing to generate sustained engagement, illustrate the material contradictions that necessitated a new form of collaborative activity.

Change is brought about through people engaging in activity, and through the theoretical lenses chosen for this study, the objective was to stimulate change by bringing people together to collaborate on a new form of outreach activity. This approach aligns with the activist and interventionist tradition of activity history (Sannino, 2011). As I noted in Section 1.2, my motivation lies in changing the persistent underrepresentation of women in computer science, informed by my dual perspective as a practitioner seeking practical change and a researcher committed to understanding the complex dynamics underpinning that change.

Drawing on Ollman (2003), I also recognise that to understand "anything in our everyday experience requires that we know something about how it arose and developed and how it fits into the larger context or system of which it is a part" (p. 13). Thus, I believe that bringing diverse groups together, as was done in the co-design process with multiple stakeholders, is crucial for generating innovative, context-sensitive outreach interventions (Section 1.4).

In answering the three research questions about what the final outreach design looks like after its co-design, and what tensions and contradictions emerge, this project aims to generate new knowledge that has not been previously known even by the participants. This reflects how Engeström describes expansive learning, as learning "what is not yet there" (Engeström, 2016b).

Rather than simply uncovering existing realities or mapping participant experiences, approaches typical of much qualitative research, this research intervenes in practice to collaboratively create something new. The use of activity theory, expansive learning and double stimulation, discussed in the following sections, provides the framework through which these dynamics are understood, critiqued and justified.

The next section, 3.2.1, briefly outlines why Activity Theory was chosen as the principal theoretical framework for this study, and how it aligns with the interventionist, practice-based aims of the project.

3.2.1 Why Activity Theory?

Activity Theory was chosen as the overarching theoretical framework for this research because of its strong epistemological alignment with the project's aims to enact change through collaborative intervention. As discussed earlier, my ontological position emphasises that understanding the world requires active efforts to change it. Activity Theory shares this emphasis, offering a dialectical and materialist understanding of human development through practical engagement with real-world contradictions. This focus on collective activity, change, and historicity made it particularly well-suited for a project centred on the co-design of a new outreach initiative aimed at addressing gender imbalance in computer science.

My background reading during the early stages of the project led me to consider other possible frameworks, such as grounded theory, phenomenology and design-based research (DBR) approaches. Grounded theory was discounted because it seeks to generate theory from data without intervening in practice. Phenomenology was unsuitable because it centres on describing lived experiences rather than collaboratively transforming activity systems. Design-based research shares some similarities with Activity Theory in its focus on designing and studying interventions, however, DBR typically positions the researcher as the primary designer, with participants playing a more consultative or responsive role. This contrasts with the Change Laboratory methodology, which is rooted in Activity Theory and emphasises co-construction and collective agency in design processes. As Bligh (2024) discusses, Engeström's notion of "design experiments" extends beyond DBR by placing systemic contradictions and collective transformation at the heart of the design process, a central tenet of the Change Laboratory approach.

Therefore, I selected Activity Theory because it offers both a conceptual lens and a set of practical tools for analysing, facilitating, and understanding transformational change, particularly through collaboration between diverse stakeholders. Its activist tradition aligns closely with the aims and ethos of my project, and its capacity to foreground contradiction, expansion, and collective agency made it a particularly suitable framework for engaging in a co-designed intervention with school and university partners.

3.3 Activity Theory

Activity theory, also known as cultural-historical activity theory (CHAT), has its conceptual roots in the works of Vygotsky (1978), who was heavily influenced by Marx, and others including Ilyenkov (1977) and Leont'ev (1978). It was further developed by Engeström (1987). Activity theory has developed into a contemporary social theory for studying change and development in human activity (Engeström and Sannino, 2021). This theory has become increasingly established internationally and is often used to analyse activity in a broad array of fields, including medical care (Engeström, 2000), sustainability (Galuppo *et al.*, 2019; Scahill and Bligh, 2022), technology use in higher education (Issroff and Scanlon, 2002, 2005), collaborative design (Zahedi *et al.*, 2017) and higher education (Bligh and Flood, 2017).

Three concepts predominantly used when speaking about activity theory are *activity*, *actions* and *operations*. Leont'ev (1978) made a clear distinction between these concepts, referring to *activity* as collective and sustained effort by humans with a shared motive regulated by an object. *Actions* are referred to as something more time-bounded and regulated by goals. They may be conducted by an individual or a collective. Each action is performed through *operations*, which are the routinised processes or procedures that respond to the concrete conditions of the moment. This hierarchical structure is often depicted using the model shown in Figure 3.1.

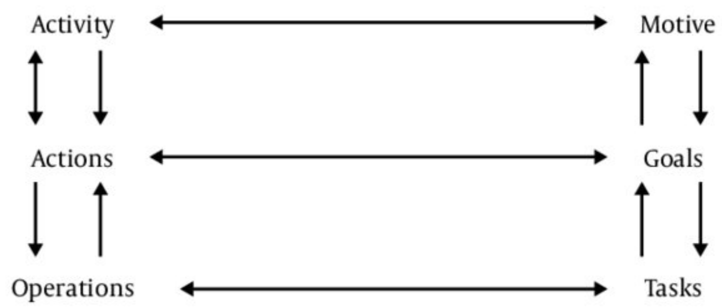


Figure 3.1: Leontiev's hierarchy of activity, actions, and operations (Leont'ev, 1978)

In the project described in this thesis, I am trying to create an activity whose object is other activities. The project's activity will be broken down into a series of actions, the nature of which actions will be discussed later in section 3.4 on Expansive Learning. According to Leont'ev (1978) the main thing that distinguishes one activity from another is the difference of their objects. It is the object of an activity that gives it a definite direction. This Change Laboratory intervention described in this thesis constitutes an activity whose object is to change other activities and in addition to this, as discussed in Section 3.3.1, the human activity involved in this project is divided up into activity systems. Like all activity systems, the Change Laboratory project that I am doing is comprised of many actions.

According to Sannino (2011), activity theory,

> throughout its history, stands as an activist theory of development of practices, which may be traced back to Marx's idea of revolutionary practice, emphasizing that theory is not only meant to analyse and explain the world but also to generate new practices and promote change (Sannino, 2011, p. 580).

Building on the rationale outlined in Section 3.2.1, this study applies Activity Theory in two principal ways. Firstly, I want to observe and analyse participants working together in different roles differentiated by speciality (areas of expertise) and authority (within some hierarchy) (Bligh and Flood, 2015). Secondly, I want to actively engage and facilitate the co-design of a new student recruitment practice and promote change. Activity theory will be used in ways that aim to help the participants analyse their own activities. Additionally, it will also be used to help me to analyse the research-intervention that the participants and I will design, this in itself will also be an activity that will be enacted within a sequence of actions.

Activity Theory, while providing a robust analytical framework, does not come with a standard method for putting its concepts and principles into practice. Instead, it offers conceptual tools that must be applied according to the specifics and nature of the objective of the activity under scrutiny as noted by Engeström (1993). By choosing to apply the conceptual tools of this theory to my project, it will shape the research design (Chapter 4) and the analysis of data (Chapter 5) throughout this study and therefore frames my overall research (Bligh and Flood, 2017).

Three principles of Activity Theory are crucial for consideration when operationalising Activity Theory concepts in this study. Discussed in the following sections, these three principles are 1) *activity systems* as the unit of analysis for activity; 2) *historicity* which looks at the history of the local activity; 3) *contradictions* as a driving force behind changing and developing the activity.

3.3.1 Activity systems

An activity system is a representation of a historically-evolved and culturally-mediated object-oriented activity (Engeström, 1987) and forms the unit of analysis. A unit of analysis, which must be focussed on some object of activity, might focus on for example; a social practice, a social system, a team working on a project, a department, or an institution (Miles, 2021). Such units represent human activity which can be understood as comprising a number of activity systems and the relations between them. While activity systems, as will be described more below, are usually understood as a set of related elements, those elements are understood only in the context of the whole.

Engeström (1987) represented this set of related elements in the form of a triangle where the subject interacts with the community, tools, rules, division of labour and the object to reach the outcome. Engeström's triangular diagram, often referred to as the activity system model, can be seen in Figure 3.2.

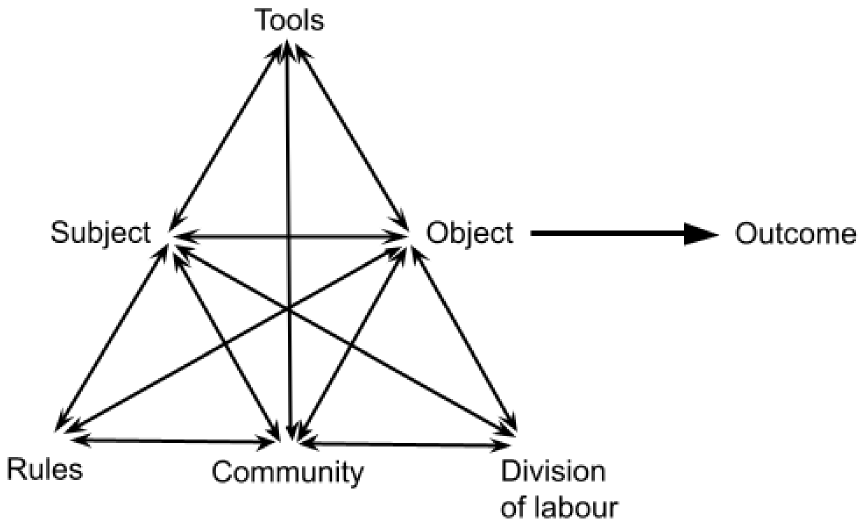


Figure 3.2: Elements of an activity system (adapted from Engeström, 1987, p. 78)

The elements of the activity system with illustrative examples of each drawn from the topic of this project can be described as follows:

- **Subject** refers to the people who are taken as the core protagonists driving the agenda of the activity system. For example: lecturers, undergraduate students, and schoolteachers.
- **Object** is what the subjects are working on in the activity system. For example: an outreach initiative and its teaching and learning activities.
- **Outcome** is an object imbued with greater sense or meaning through transformation. For example: an outreach initiative that attracts more female school students to consider studying computer science at undergraduate level.
- **Tools** represents the items used by the subject to pursue their object. For example: computers, video-conferencing software, and e-whiteboard.

- **Rules** refer to the implicit and explicit rules and regulations of the context that are bound to affect, in one way or another, the means by which activity is carried out. For example: resources and curriculum progression.
- **Community** represents the other people who are engaging with, contributing to, or being impacted by the project, even while not its core protagonists. For example: school management, school students.
- **Division Of Labour** relates to the allocation of tasks, usually because of authority (vertical division) or specialism (horizontal division). For example: shared roles and responsibilities during design process.

Activity systems do not exist in isolation and are 'always a node in a network of functionally interdependent activity systems' (Virkkunen and Newnham, 2013, p. 35). As seen in Figure 3.3, the activity system model is thus expanded to include a minimum of two activity systems to illustrate when these activities come into interaction with one another, their objects start to interact. The subjects from the two different systems can act on a partially shared object at the same time while also acting on their own objects. This interaction and engagement between people from two activity systems allows those from one activity to better understand what is happening in the other activity system (or world).

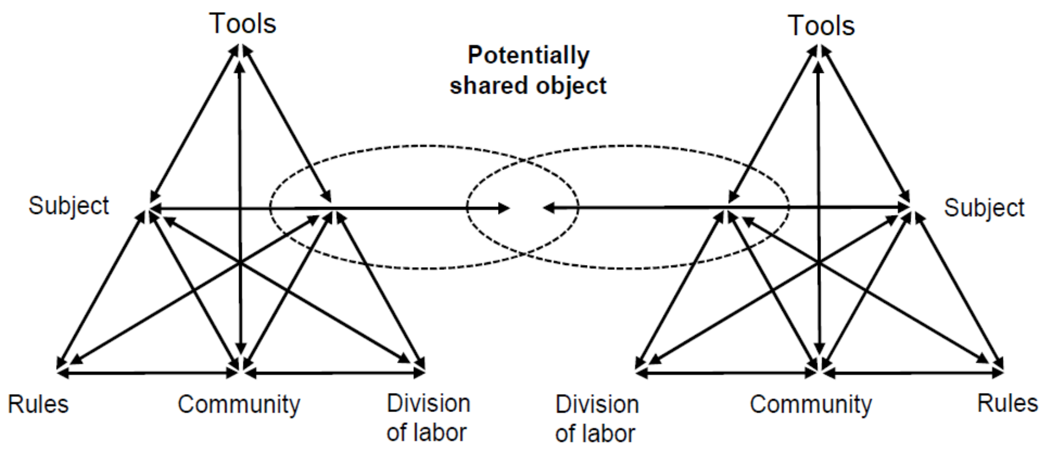


Figure 3.3: Activity as a dynamic model of interacting activity systems

In the context of this study, which involves a partnership between two institutions: a university and a secondary school, the participants from both partners will use the activity system model to analyse their own practices in their context and design new ones, thus guiding knowledge production during the intervention.

For illustrative purposes only, let us imagine an example of these two intersecting activity systems in this partnership where both institutions are working towards individual and collective goals, illustrated in Figure 3.4. This diagram was created to help understand the interaction between both contexts and is a representation of my assumptions at the beginning of the project. The activity system on the left represents the current recruitment practices of the university's computing department and the activity system on the right represents the schools current practices around offering its students computing curriculum.

Central to this study, the activity system model provides a tool for exploring the shared object of both institutions and what the subjects are working towards in their own activity systems, their shared motive to promote and expose students to computer science.

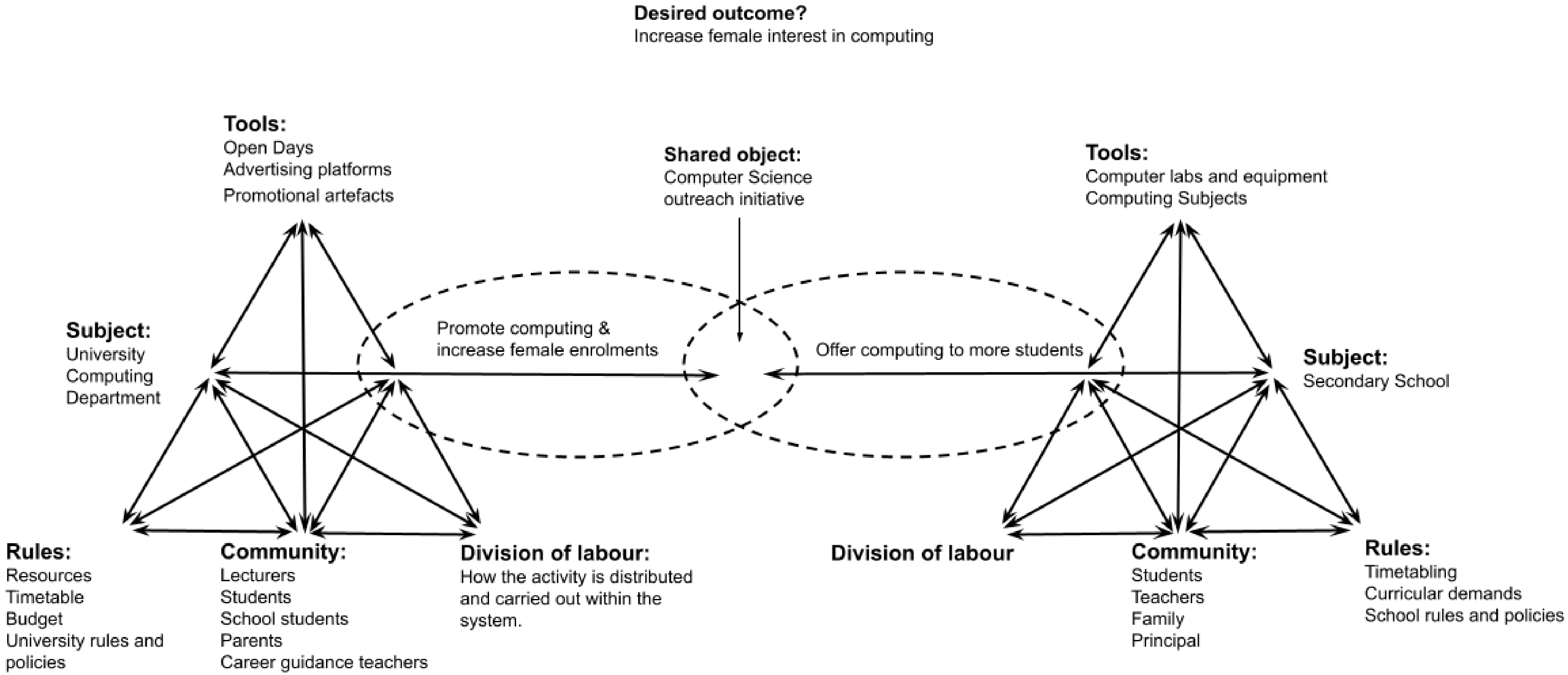


Figure 3.4: Conceptual illustration of co-design activities for the outreach initiative (for illustrative purposes).

3.3.2 Historicity

The current form of any activity system has been arrived at as a consequence of its prior history of posing and overcoming contradictions. In other words, activities develop over time, arising out of prior forms and developing onwards into new forms. As such, 'their problems and potentials can only be understood against their own history' (Engeström, 2001, p. 136).

In order to understand the current form of an activity system, it is necessary to study the activity systems prior forms, it's history over time. The action of historical analysis which I will discuss below in section 3.3.3 is an attempt to try to look backwards in time and map that. For example, in this study, I will trace the historical development of the recruitment practices of a university computing department and devise a timeline charting the past cycles of the activity system that are identified. This awareness of the history of activity systems will help both myself as researcher-interventionist and the participants to understand how existing problems in recruiting underrepresented students have arisen as a consequence of earlier iterations of practice as well as to see the potentials of a newly designed outreach initiative.

3.3.3 Contradictions

One of the central tenets of activity theory, and central to dialectics, are contradictions which are the 'historically accumulating structural tensions within and between activity systems' (Engeström, 2001, p. 137). Contradictions play a key role in driving change and development of an activity system. Activity Theory provides a dialectical perspective on the ways in which activity develops because of and through the contradictions that emerge as participants engage with it.

Engeström and Sannino (2011) suggest that contradictions cannot be observed directly and that their existence can only be identified by analysing their manifestations (p. 369). As we have no direct access to contradictions, sustained effort is required to aggravate and expose them (Moffitt, 2018). Contradictions are "considered as systemic features of activity that are manifested in subjective experience (as dilemmas that people experience)" (Scahill, 2021) and so an intervention that involves analyses of activity systems provides an opportunity to identify contradictions. The manifestations of contradictions are found in the discourse of participants as they discuss ways new or alternative methods of activity that resolve their practice-based problems and challenges (Cakir *et al.*, 2022).

Four forms of contradictions, illustrated in Figure 3.5, may arise within and between activity systems and these can be distinguished as:

- **primary contradictions** can exist *within elements* of the activity (for example within the division of labour where a particular task might be assigned to two different groups of people who have conflicting views about priorities)
- **secondary contradictions** can exist between elements of an activity system (for example when a new practice clashes with existing rules or established practices)
- **tertiary contradictions** may arise between the *existing forms* of the activity system and *attempts to apply* a new model (for example as new rules or practices are formed to accommodate a new practice)
- **quaternary contradictions** where two interacting activity systems are in conflict (for example when co-existing activities (e.g., activities of school and university) have conflicting objectives, rules, or divisions of labour)

(Engeström, 1987/2015 in Bligh & Flood, 2015)

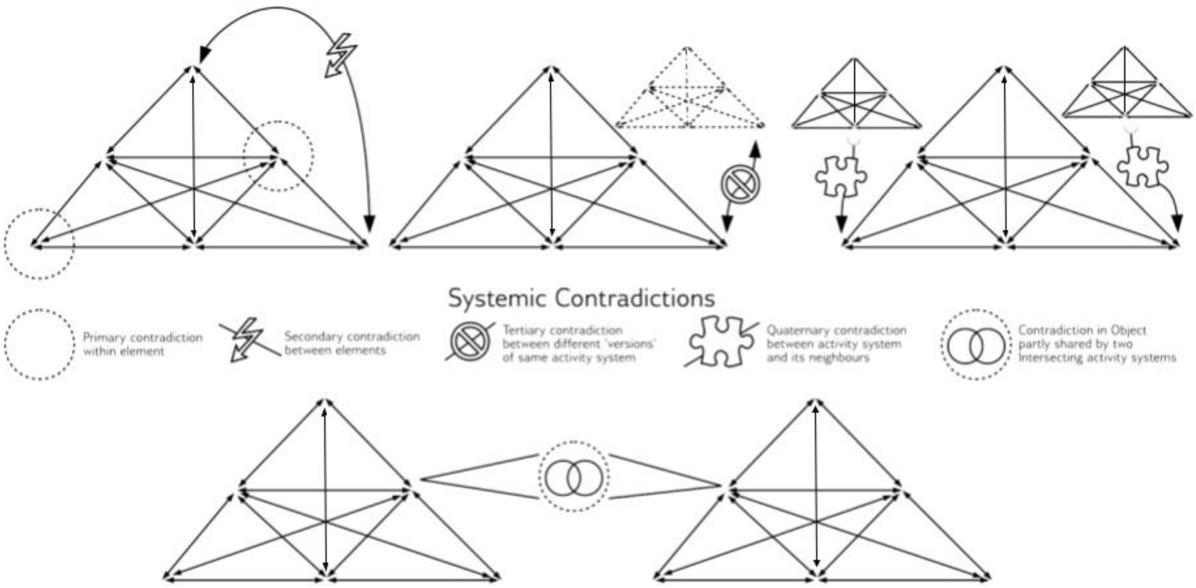


Figure 3.5: A graphical representation of systemic contradictions (Bligh & Flood, 2015)

As schoolteachers discuss and understand the historical reasons for tensions in their activity (for example the absence of a computing subject for second and third year students), they can begin to explore potential solutions. Likewise within the university computing department, a key contradiction that they seek to address is the persistently low number of females enrolling in their courses, despite ongoing recruitment efforts. When participants in either activity system begin to implement changes, such as adopting new tools, introducing new rules, or engaging in collaboration across systems, new contradictions often emerge. This process highlights a fundamental principle of activity theory, contradictions are not only sources of tension but also drivers of change. As people pose solutions to existing contradictions, they inevitably introduce new ones. It is a continuous cycle of contradiction, resolution, and re-emergence that underscores the dialectical nature of activity theory. Change is thus understood not as a linear progression toward a fixed goal, but an ongoing dynamic feature of activity that never reaches a final or stable state.

The tensions and contradictions that emerge within and between the activity systems from both institutions of this study will provide insight and understanding about potential starting points for shifts in change and development of recruitment practices.

Participants will need to engage in understanding contradictions in a number of ways. They will need to explore the contradictions in current activity systems to understand the potential for change and development. They will need to be aware of the contradictions in previous activity systems that led to current activity systems being developed in the first place. And they will explore the contradictions in their own future-oriented models of activity as they seek to develop them over the course of the project.

Any emerging contradictions that challenge the design of the outreach may qualify as sources of future change and development in Engeström's sense (Engeström, 2001, p. 137) and function as instigators of expansive learning. It is my understanding that any contradictions that emerge during the design process of this project, some or all of which may be resolved, within or between the subjects of the activity systems, will be valued as essential to the expansive learning process. And therefore, new forms of activity emerge. Those new forms of activity could then be understood as solutions to the problem identified locally, or the *outcome* of the intervention.

3.4 Expansive Learning

The CHAT informed theory of expansive learning, was first articulated in the late 1980's by Yrjö Engeström (Engeström, 1987) and is used to explain and guide collective redefinition or radical change of an activity. The aggregation of contradictions in an activity can provoke participants into analysing, experimenting with and reconceptualising the object of their activity (Engeström, 2014). Expansive learning is seen as successful if the efforts of subjects lead to the formation of a new, ‘expanded’ object and pattern of activity oriented to the object (Engeström and Sannino, 2010, 2021). This type of learning is different to traditional modes of learning where the content to be learned is known in advance, expansive learning is understood as a collective process of developing something that is not yet there (Engeström and Sannino, 2010). In other words, when collaborating over some societal problem that needs to be resolved, subjects do not know in advance exactly what needs to be learned to resolve it.

One of the strengths of the theory of expansive learning is that it sets out how the process of learning is performed in practice by defining a cycle of seven learning actions, depicted in Figure 3.6. Engeström (2016b) states that where expansive learning successfully occurs, whether in research-interventions or otherwise, subjects will have undertaken a range of those learning actions whose goals can be categorised into the following ideal-types (pp. 47–48), described by (Moffitt and Bligh, 2021) as:

1. **Questioning**:- rejecting or criticising some aspects of the existing activity, wisdom or current plan.
2. **Analysis** (actual-empirical and historical): investigating and analysing the present activity and earlier activities that lead to the current days method of practice.
3. **Modelling**:- constructing a simplified model of a new idea that offers a perspective for resolving or transforming the present activity.
4. **Examination**:- exploring the dynamics, potential and limitations of proposed models by running, operating and experimenting with them.
5. **Implementation**:- practical application of models and assessing how they work in practice.
6. **Reflection**:- reflecting on and evaluating on the process to change activity and identifying needs for further learning and development and drawing of conclusions.
7. **Consolidation**:- establishing models as new stable forms of practice.

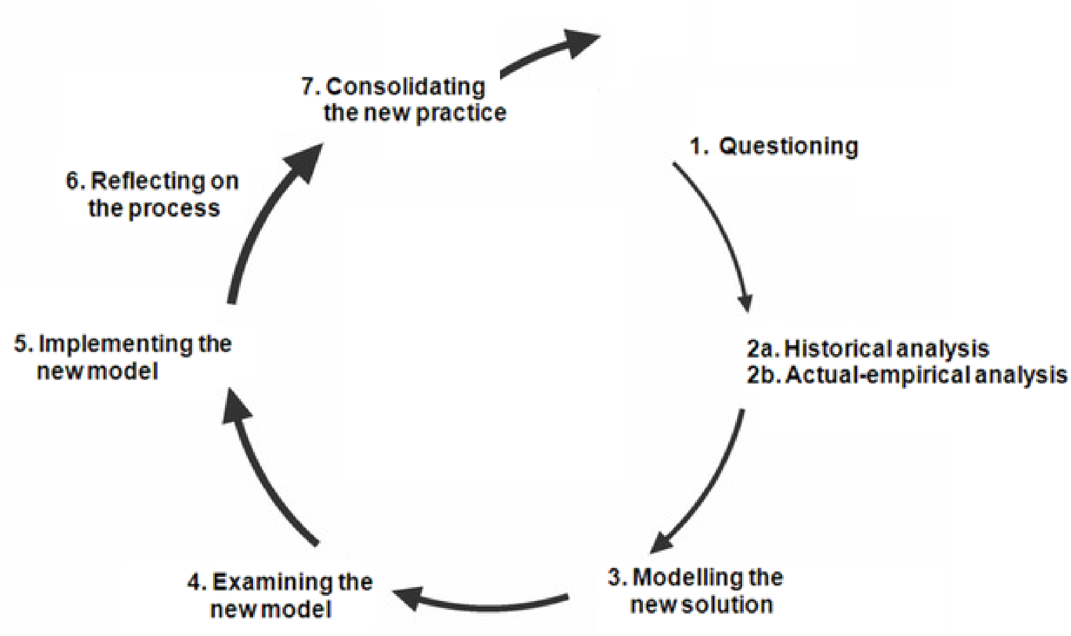


Figure 3.6: Cycle of expansive learning (Engeström, 1999)

As mentioned in Section 3.3, *actions* relate to the quest to achieve the activity's goals and these actions are conducted by individuals or a collective and *activity* relates to the collective and sustained effort by humans with a shared motive regulated by an object. Expansive learning is aimed at guiding collective transformation efforts in organisations and workplaces in which participants, through these analytical learning actions, change and create new activities by going beyond the already known.

By employing the expansive learning cycle in this project, it will assist me in designing a research-intervention to provoke or accelerate expansive learning. It will serve me during the Change Laboratory sessions as a guide for strategic thinking about how the design of the initiative unfolds and how to manage it. It is not expected that this will not occur in a linear fashion and that the cycle will not always flow smoothly. It is expected that there will be many false starts and returns to earlier moments (Bligh and Flood, 2015) in the expansive learning cycle.

The expansive learning cycle will serve me as a guide to think about the goals of the various actions I am aiming to pursue when designing tasks. For example, I will *design a task* whose *goal* is to *question* current computing practices in both institutions (the recruitment practices in the university computing department and the computing subjects offered to students in the school). Another example of a task I will design whose goal will be to *analyse* the current activity based on its historical development (section 3.3.2) and to think about an expansive transformation of the activity system. The expansive learning process in a formative intervention, discussed in Section 3.6, also contains non-expansive actions that can lead to the emergence of expansive learning actions (Bal *et al.*, 2019). These include "presentation and discussion of the issue prepared for the team, not initiated and constructed by the team" (Engeström, 2008, p. 133). Examples of non-expansive actions in this study might include informing, clarifying, and summarising past and current figures of female and male students enrolled on computing courses in the university and, computing subjects in the school.

The intention is for the participants and I, all of whom have prior knowledge about the object to learn "something that is not yet there" (Engeström and Sannino, 2010), new knowledge, amalgamated by interaction and collaboration, built in a shared way.

3.5 Double Stimulation

Double stimulation is referred to in the literature as a principle and a method designed to help participants develop their own sense of volition. It supports participants not only in addressing difficult tasks and taking collaborative action to change their activity, but also in fostering increased agency in the process Sannino (2011) describes the principle of double stimulation as "the mechanism with which human beings can intentionally break out of a conflicting situation and change their circumstances or solve difficult problems" (p. 584). Building on this, Sannino (2015) later conceptualised Transformative Agency by Double Stimulation (TADS), highlighting how individuals and collectives gain the capacity to take initiative and author new forms of activity through the double stimulation process. TADS captures the moment when participants begin to resist the status quo, question current practices and envision and enact alternative futures.

Tasks within a Change Laboratory project are inspired by Vygotskyan dual-stimulation designs. According to Virkkunen and Newnham (2013), task designs must carefully consider a range of elements to support this development process, as outlined in Table 3.1.

Table 3.1: Aspects of Task Design

Term	Description	Hypothetical Examples
Mirror-data	Materials used to represent practice problems and contradictory situations to participants	Statistics illustrating gender imbalance in first-year enrolments on computer science programmes
First-stimulus	The task specification which subjects are given the goal of addressing	What are your experiences surrounding the number of female students in your classes?
Second-stimulus	The *analytical tool* or *method* to be used for addressing the first-stimulus task	Individual or group answers recorded digitally on online project workspace
Social organisation	The flow of participant work, considering moments of whole group, small group, or individual working	Whole group divided into two smaller groups to discuss and present
Documentation	How individuals or sub-groups externalise their thinking for discussion with others	Timeline drawn that maps historical development of activity
Discussion & recording	How people come together to discuss tasks and debate solutions, and how those discussions are recorded in ways that can be re-used later	Online meeting hosted using a video conferencing tool with recording features such as Zoom

Recalling the expansive learning cycle in Section 3.4, we might set a goal for the task which is questioning, or modelling. When the first-stimulus is introduced, the subject focusses on the overall goal of the task, the 'problematic situation'. However when the second-stimulus is introduced the subject focuses on using the analytical tool or method to address the first-stimulus task (Bligh and Flood, 2015).

When faced with a problematic situation, humans can become paralysed by conflicting motives for their actions and need external artefacts to gain control of the situation (Augustsson, 2021). Double-stimulation enables subjects to transform a problematic situation in which they may have conflicting motives. This is achieved by designing the first-stimulus task in such a way that it cannot be addressed by the subject acting alone; it requires them to "break out of a conflicting situation and change their circumstances" (Sannino, 2011, p. 584).

Double stimulation is integrated into this formative intervention (explained in section 3.6) where I as researcher-interventionist use double stimulation to underpin the design of specific tasks in the Change Laboratory workshops. The workshop tasks will be heavily focused on achieving the goals of actions within cycles of expansive learning, and this makes double stimulation appropriate for this study.

For illustrative purposes only, let us imagine that in the first workshop I present data (first-stimulus) highlighting the problematic aspects and disturbances to participants of their daily activities, in order to trigger recognition of the need for change. This could take the form of statistics and audio-visual materials. I then support participants by providing opportunities to confront these issues by questioning and critiquing past and present outreach practices. Participants work collaboratively on this shared 'problem', which they are motivated to address. Subsequent workshops, inspired by the principle of double stimulation and aligning with the expansive learning cycle, might involve designing, evaluating, and reflecting on new models of outreach activity.

3.6 Formative Intervention

An intervention has been described by Virkkunen and Newnham as "purposeful action by a human agent to support the redirection of ongoing change" (Virkkunen and Newnham, 2013, p. 3). A formative intervention, or what Virkkunen and Newnham also refer to as a research-intervention, is one in which interventionists and practitioners collaborate to explore solutions to real problems faced in workplace activities (Sannino *et al.*, 2016). Inspired by Vygotsky and other activity theorists, Engeström characterises a formative intervention to be 'a radical methodological approach' (Engeström, 2016, p. 210). Sannino et al. (2016) capture the concept of a formative intervention nicely through their use of two key phrases collective design and collective analysis.

Since the 1990s, formative interventions have been applied in a wide range of domains, including healthcare, education, media, agriculture and social welfare (Bal, 2018; Sannino et al., 2009). In each context, local stakeholders play a central role in collaboratively redesigning the activity systems in which they work (Bal, Afacan and Cakir, 2019). The purpose is not to insert externally created solutions but to stimulate expansive learning within the system, where participants develop new concepts, models or practices that address their own contradictions. Double stimulation, discussed in Section 3.5, often serves as the mechanism for surfacing and working through those contradictions.

This study is a theoretically driven *research-intervention*, with dual aims, to support transformative change in the activity systems under investigation (a university outreach team and a secondary school), and to generate new knowledge about the collaborative design of gender-equitable computing outreach within a real-world educational context.

The Change Laboratory (CL), first developed by Engeström in the 1990s, is the specific model of formative intervention adopted in this study. While formative interventions in general aim to support locally led transformation, the Change Laboratory offers a systemic, theory-based structure for achieving this. A key distinction of the CL is that it integrates the conceptual tools of activity theory and expansive learning into the intervention process itself. This allows participants not only to diagnose problems but to reconfigure their practice over time through iterative cycles of reflection, modelling and experimentation.

The Change Laboratory provides a space where practitioners, supported by a researcher-interventionist, critically examine the historical development of their activity, identify tensions and contradictions, and construct new models of practice. Importantly, these models are not prescribed in advance but are generated within the intervention as part of the learning process.

In this study, the CL was particularly well suited for several reasons:

- It allowed for the active involvement of stakeholders (schoolteachers, university staff, undergraduate students) in analysing and redesigning their own outreach and educational practices.
- It provided a framework for making contradictions visible and discussable, especially those embedded in current gendered patterns of participation in CS.
- It supported the creation of a locally responsive outreach programme, not through top-down design but through joint modelling of a new outreach activity.
- It aligned closely with the epistemological stance of this research, which views knowledge as generated through collaborative, practice-based transformation (see Sections 3.2 and 3.2.1).

This approach stands in contrast to design-based research, which according to Engeström, follows to some degree a more linear view (Engeström, 2016a). In such approaches, researchers typically design the intervention in advance and then pass it on to the practitioners to implement. The problem with this model, as Engeström argues, is that "nobody asks who does the design and why". In contrast, a formative intervention begins with a problematic situation as encountered by participants, not with a pre-defined solution. Key distinctions include: 1) participants are directly engaged in the design process, 2) the design effort is embedded in a broader process of expansive learning and 3) the goal is not to scale or replicate a finished solution, but to support locally developed, generative change over time.

Action research was another possible approach I considered. However, Bligh and Flood (2015) note that action research is more focused on person-to-person discourse, rather than the mediation of activity through artefacts and systems. Virkkunen (2006) further critiques action research for concentrating on individual tasks rather than on systemic, collaborative activity across entire activity systems. Given that the aim of this project to engage in expansive learning and the development of new concepts and tools, the action research approach was unlikely to support the scale of systemic transformation intended here, and was therefor not selected.

In summary, the Change Laboratory, discussed in more detail in Chapter 4, was selected because it enables the co-production of knowledge through activity-oriented intervention. It does not impose change but creates conditions for stakeholders to collaboratively design solutions that are contextually grounded, historically informed and future-oriented. This aligns fully with the aims of my thesis, not only to develop a locally relevant outreach initiative but to understand and document how change happens, through collective engagement with complex, situated problems in education.

3.7 Summary

This chapter has set out my research underpinnings and provided an explanation of the theoretical framework chosen. In Chapter 4, the Research Design chapter, I explain how I use Double Stimulation to design the tasks of the Change Laboratory workshops, in addition to how Expansive Learning and its learning actions guide the overall strategy of the workshops. In Chapter 5, I use Activity Theory to analyse the research-intervention that I design with participants.

Chapter 4 Research Design

4.1 Introduction

In this Research Design chapter, I set out my empirical approach to exploring the co-design of an outreach initiative to attract female students into higher education computer science, which was motivated by my professional experiences and my position in the university computing department of this study.

As set out in my Theoretical Framework (Chapter 3), my approach is underpinned by the belief that we can only learn about the world by trying to change it. The objective of this project is not simply to produce an outreach initiative better than those that already exist in the world but to try to understand better through intervening to change existing practices. I want to produce research knowledge that will more appropriately contextualise outreach intervention designs and to do this I have designed my research project in the way described in this chapter.

As outlined in the Literature Review (Chapter 2), the design process for outreach initiatives, particularly those aimed at gender equity, remains relatively underexplored in the literature. This research seeks to address that shortcoming by exploring how an outreach initiative can be collaboratively developed by participants from both secondary and higher education contexts, and what that design process reveals about the local context in which it occurs.

In the remainder of this chapter, I introduce the Change Laboratory methodology I have chosen for this project. I then outline the process of selecting the intervention unit, reflect on my role as an insider-researcher, and describe the recruitment and selection of participants, the planning, data collection and analysis strategies used throughout the project. Finally the ethics, and the limitations and challenges of the research design will be discussed.

4.2 The Change Laboratory Methodology

In Chapter 3, I outlined the reasons why I chose to undertake a formative intervention. I emphasised that this approach is about trying to foster expansive learning using double stimulation to promote change in activity.

The Change Laboratory is a type of formative intervention that uses the principles I have described in Chapter 3 in a particular kind of way, for the development of work activities by practitioners in collaboration with researcher-interventionists (cf. Virkkunen & Newnham, 2013). It involves a series of collaborative tasks undertaken in workshops, with the aim of fostering expansive learning cycles where participants, in this case people from a university-school partnership, are able to analyse existing practices, identify any tensions and contradictions within their practices (activity systems), and collaboratively design and model new ways of working (Engeström, 2001; Engeström and Sannino, 2010). Employing the expansive learning cycle within a Change Laboratory intervention provides the space to provoke or accelerate expansive learning among participants, and by doing this the aim is to produce new knowledge, which the participants do not already know.

A well-known example is a Change Laboratory conducted in a university library (Engeström *et al.*, 2013; Sannino *et al.*, 2016) where the researcher-interventionists collaborated with the library staff, management, and agents from four university research groups in social sciences and humanities. Their aim was to create a new library service that would attract more visitors by redefining the services that the library offered to its research groups in addition to its means of organising work. The interventionists found that the participants designed and implemented new services and, in the process, came to produce new knowledge about the inadequacies of prior services as a result of partaking in the Change Laboratory. The researcher-interventionists identified and systematically analysed the expansive learning actions the participants took during the Change Laboratory. They found that six of the seven expansive actions transpired throughout the process and that while participants deviated from the initial plan, the process then returned to follow the cycle. Such deviations from the plan and from the cyclicity of the process can be viewed as signs of expansive learning and a necessary action.

As outlined in Chapter 1, my motivation for this project is to develop new insights into how to change the current gender imbalance in computer science in higher education and so when choosing a methodology, I knew I needed one that I could get good insight into the structures causing this gender imbalance and then try to change those structures. The methodology needed, was one where I could engage in an intervention project, to get stakeholders involved, and to really try and design something new together. A space would be needed where we could collaborate using multimodal material to develop or produce other activities in whatever format needed. I believe that doing this will help me to produce new knowledge that can be of benefit to the literature in areas such as those discussed in the Literature Review in Chapter 2.

Upon consideration of other methodologies and data collection methods such as interviews, questionnaires and case studies, I concluded these would not produce the kind of knowledge I was looking for. I would not get the kind of insight I needed from a questionnaire or interview and doing a case study would only allow me to describe the current situation rather than attempt to change it.

I chose to employ a Change Laboratory intervention as my research methodology with the intention of creating the space where stakeholders can work together to co-design new activities. In doing so, I hope to document the design process by stakeholders, which will be new knowledge in itself and to show how the design is contextualised, by tracing the process and showing how the people came up with it. My methodological considerations were largely influenced by the guidance provided by Virkkunen & Newnham (2013) in addition to the work of others such as Bligh & Flood (2015); Hasted (2019); Scahill (2021). Of course, I needed to adapt that guidance and produce a project appropriate to my own conditions, as I describe below.

4.3 Selecting the Intervention Unit

The literature on the Change Laboratory suggests that projects following this approach should start out by choosing the intervention unit that is to be the focus of the change (Virkkunen & Newnham, 2013, p. 65). It is understood that any unit could be an intervention unit, but the initial selection of a unit is consequential and should be considered strategically. In the context of higher education, choosing an intervention unit can be challenging, “a local unit is needed that manifests the interest and capability needed for development” (Virkkunen & Newnham, 2013, p. 65). Choice of units may also be constrained due to the researcher already being employed there and having access to it. Virkkunen and Newnham suggest identifying a unit that greatly experiences the need for change, which the management and staff are interested in, and which is capable of developing new models of activity with the support of external researcher-interventionists (p. 65)

As outlined in previous chapters, the overall aim of this project is to design an outreach initiative to expose school students to computer science and tackle the gender imbalance currently seen among computer science students in higher education. To do this I required an intervention unit comprised of a higher education institution and a secondary school, where each of their activities experienced a need for change, with the intention to bring both of these activities systems together, as discussed in Chapters 1 and 3.

The intervention unit that I selected comprised of one computing department from a multi-campus university in Ireland and a secondary school located near one of its campuses. As discussed in detail in Chapter 1, this selection was based on two key factors, the university's Department of Computing was experiencing a significant gender imbalance within its computing programmes, and the secondary school was reporting low levels of student interest in the computing subjects it offered. Together, these two institutions formed a suitable pilot unit for this intervention.

This project is based on an existing university-school partnership between the university's computing department and the local secondary school. While the institutions had previously been in discussions, this project marked the first time they worked together to co-design an outreach programme. The existing relationship provided a foundation for deeper collaboration, enabling the formation of an agreed intervention unit at the outset of this work.

Historically, outreach and recruitment in computer science education has been characterised by recurring tensions between the aspirations of initiatives and the structural realities of institutions. Common contradictions in this domain include mismatches between outreach goals and institutional priorities, tensions between short-term project funding and the need for sustained engagement, and disparities in access to computing resources between schools. In this context, the selected intervention unit, a university computing department and a local secondary school, reflected many of these typical challenges while also presenting unique features. For example, both institutions recognised a clear need for change (gender imbalance and low interest in computing subjects), but they operated under different calendars, assessment systems, and resource constraints, all of which had the potential to generate secondary and quaternary contradictions once collaboration began. These historical patterns of tension underscored the suitability of the unit for a Change Laboratory, as they provided fertile ground for surfacing and working through contradictions.

4.4 Insider-Researcher

I conducted this qualitative study in the institute where I am employed and with participants whom I work with, more specifically in the computing department which is one half of the partnership of this intervention. Therefore this research could be described as 'insider' research (Trowler, 2016, p. 240) within one partner institute, but not within the secondary school which forms the other half of the partnership.

My intent with choosing the computing department where I work, as discussed in Chapter 1 where I discuss my motivation for this project, was to actively intervene and achieve change within the context where I work. This insiderness within my department afforded me many benefits and opportunities in addition to some challenges and limitations.

One challenge for an insider-researcher is to recruit participants that are inclusive and representative within the practical limitations of the research context. Bligh and Flood (2015) who discuss insider research (p. 12) acknowledge that 'participant selection processes might be easier for insider researchers due to greater familiarity with local dynamics'. Therefore one of the benefits of being an insider-researcher for me included access to communicate with and recruit staff members. Another challenge I was cognisant of from the beginning was that I would need to be sensitive to participants' opinions and actions throughout this study as they engaged with me in this formative intervention.

4.5 Participant Recruitment

Change Laboratory sessions typically involve fewer than 20 people, for reasons of resource and participation management (Bligh and Flood, 2015). The selection of participants requires consideration of people who "are dealing with the same object in their daily work and are involved in realizing the same final outcome despite differences in their occupation, task or hierarchical position" (p. 65). Such participants must speak openly and directly about practice problems and possibilities for change. Thus, "there is desire to capture an appropriate range of voices to gain better insight and generate support for change while trying to ameliorate the likelihood of local hierarchies stultifying contributions" (Bligh and Flood, 2015).

I decided to recruit participants through purposive sampling with the intention of identifying and selecting people based on their insights, experiences and expertise within their organisation and computer science education and who were advocates for increased female participation. My aim was to recruit and select approximately 10-12 participants from across the university and local school. In consideration of group composition and to ensure a spread of roles, specialisms and levels of authority, I targeted faculty, students, and management from the university's computing department, as well as teachers from the local secondary school.

Although this research is concerned with addressing the underrepresentation of female students in computer science, the goal was not to create a group of exclusively female participants. Rather, the intention was to create a diverse group of stakeholders, including male and female participants, who each engage with the problem from different positions and institutional perspectives. Gender balance was not the aim in itself, rather, it was important to include those who are in positions of influence within the systems in question and who have a stake in addressing the issue. An all-female participant group would risk excluding key perspectives and systemic insights that are essential for generating sustainable and collective solutions.

The process I followed to recruit participants of these types is outlined in the following sections.

4.5.1 University computing department

In the university department, potential participants were selected based on meeting the following criteria:

- they must fall into one of three categories of roles and authority (e.g. student, faculty, management)
- from varying speciality in computing (for example cybersecurity, software development, computing networking).
- there must be a good balance of male and female participants
- those with prior experience with outreach initiatives or specifically female recruitment
- anyone who expressed an interest in being part of the research project (emails were sent to staff and students outlining this project and its goals) and boosting female participation in computer science.
- they must be available on Friday afternoons between 1pm and 3pm to attend sessions.

To recruit such university participants, networks of the department of computing and the researcher were used. As mentioned in Section 4.4, I am employed in the department and so this insiderness afforded me many opportunities including access to communicate with staff. Participation was open to all staff in the department of computing and so to recruit faculty and management, I sent an email to all department staff inviting them to take part in my research project. Direct contact was also made with colleagues whom I already knew had a keen interest in boosting female participation in higher education computer science.

To recruit students, the school office sent an invitation to all first and second-year undergraduate computing students to take part. Those student groups were targeted because they might be able to relate to the computing needs of secondary school students in addition to being valuable role models when piloting the outreach initiative. In addition to this, third and fourth-year students would not be in a good position to commit to this project due to work placements and final year projects.

Those who responded to the email expressing interest were contacted individually to review their suitability (meeting the criteria above) and I was fortunate to receive enough interest from people who collectively together met the criteria I was aiming for. In total, five lecturers (excluding me as the researcher-interventionist), three students and one manager were recruited from the university computing department.

Over time, the university computing department had engaged in various outreach activities — from open days and women in engineering an computing seminars to collaborations with local schools, yet these efforts often revealed contradictions in practice. For instance, while outreach was valued by individual staff members, it sometimes conflicted with teaching loads or departmental priorities, creating secondary contradictions between rules and the object of widening participation. Similarly, there were quaternary contradictions between the department’s activity system and those of partner schools, such as differing expectations about staff availability or resources. These historical tensions informed the department’s readiness to engage in a more structured, co-designed initiative, as there was recognition that previous efforts, while well-intentioned, had not fully resolved these underlying systemic issues.

4.5.2 Secondary school

During my initial visit to the school, as described in Chapter 1, it was decided that the ICT teacher would recruit other schoolteachers, verbally or through direct email. The aim was to recruit schoolteachers who:

- had insight into the outreach needs of the school
- expressed an interest in being part of the research project and boosting interest in computer science
- would provide a good balance of male and female participants

The participants from the school were therefore enlisted through direct contact by the main ICT schoolteacher. In total five schoolteachers were recruited from the school who met the agreed criteria. In addition to the main ICT teacher who teaches the majority of computing-related subjects in the school, two other teachers who agreed to participate also teach ICT alongside their core subjects as illustrated in Table 4.1.

The secondary school's history with computer science education also contained several notable contradictions. For example, while there was enthusiasm among some staff for promoting computing, limited timetable availability, resource constraints, and the absence of a continuous computing pathway in the junior cycle created secondary contradictions between mediating artefacts (such as available ICT facilities) and the object of fostering sustained student engagement. Additionally, changes in national curriculum policy had occasionally introduced quaternary contradictions, where external expectations did not fully align with the school's local context or priorities. The recruitment of participants for this study therefore brought together teachers with first-hand experience of these challenges, positioning them well to engage in the Change Laboratory process of surfacing and addressing historical and ongoing tensions in computing education.

4.5.3 Researcher-interventionist

The researcher is also directly involved in the CL process together with the participants and acts not only as designer of the sessions but is also a participant in and analyst of the process (Engeström *et al.*, 2003). My intentions as researcher were made explicit to the fourteen other participants from the beginning and taken into consideration throughout the CL process and data analysis.

A table detailing the profiles of the 15 participants of this CL project, using pseudonyms, is given below in Table 4.1.

4.5.4 Participant summary

Table 4.1: Summary and pseudonyms of participants

Pseudonym / Role	Speciality	Gender
School participants:		
Schoolteacher 1	ICT	F
Schoolteacher 2	Special Education Needs and ICT	F
Schoolteacher 3	Science and Maths	M
Schoolteacher 4	Metalwork and Engineering	M
Schoolteacher 5	English, Religion and ICT	F
University participants:		
Undergraduate student 1	Software Development (2nd year)	M
Undergraduate student 2	Digital Art and Design (1st year)	F
Undergraduate student 3	Cybersecurity (2nd year)	M
Head of Department	Computing	M
Lecturer 1	Data Structures and Algorithms	F
Lecturer 2	Software Development	M
Lecturer 3	Cybersecurity	M
Lecturer 4	Computer Networking	F
Lecturer 5	Operating Systems	M
Lecturer 6*	Systems Administration	F

* also the researcher-interventionist

NOTE: The pseudonyms listed in the first column of Table 4.1 are used when quoting or referring to participants in the text. These pseudonyms can be used to differentiate between participants and their different roles, hierarchy and speciality. When including statements made by participants during workshops, I will use a denotation referring to the specific participant and workshop, as listed in Table 4.1. For example, "Schoolteacher 1, W5" indicates a statement made by Schoolteacher 1 in Workshop 5.

In reference to Virkkunen and Newnham who recommend selecting participants "who are dealing with the same object in their daily work", I believe I have met this need in the university by recruiting those who have an interest in tackling the underrepresentation of females in computer science. However as this is a partnership between a university and a school where our aim is to co-design an initiative, I also needed additional stakeholders to be involved, namely schoolteachers and undergraduate students. It was hoped that by involving this heterogenous group of participants would ensure a broad perspective to co-design an outreach initiative that responds to the local issues identified by both contexts and built on existing culture and resources. I believe this was adequate to explore my research questions.

4.6 Planning of the Change Laboratory Project

4.6.1 Initial planning meetings with computing department and school

In October 2021 I had a meeting with my manager, the Head of Department (HoD) for Computing, to introduce the project I had in mind for my PhD research. During the meeting I described what I anticipated the project would entail and the benefits it may produce for the department. This was a highly positive meeting and my project was received well by my HoD who offered his support and contact details of the ICT teacher in Tullow Community School as a potential secondary school to approach, as described in Chapter 1.

The schoolteacher responded to my initial communication showing strong interest to participate and from there we arranged a meeting in November, where I visited the school for an informal chat about this project. During this meeting, I was able to evaluate the school's suitability. Follow-up actions were agreed and from there we collaborated over aspects such as teacher recruitment and sessions. As I was on maternity leave during this time, we set a preliminary date for the first workshop for the last Friday in February 2022 that would suit the school timetable and my return to work. In the meantime the ICT teacher would recruit other teachers in the school to participate and I would recruit university participants and plan the sessions. Recruitment took place over two weeks and as discussed in Section 4.5.

Following recruitment in both institutes, I arranged an internal meeting in early March with faculty and management participants within the Department of Computing to have an initial discussion about the project at a very high-level and to set expectations/goals for this project.

Virkkunen and Newnham (2013) advise when considering the design of a Change Laboratory, one of the first issues to consider is how to construct, in conjunction with the investigated organisation, 'an initial shared idea of the object of the research-intervention' (p. 61). Five out of seven faculty and management participants attended this meeting which lasted 30 minutes. Student participants were not invited, because one of the planned topics for discussion was students in general and to get clarity from the HoD regarding a variety of topics such as availability for sessions, cover for lectures if needed, and garda vetting. The main objective was to get a sense of what was feasible. We also discussed certain student cohorts and if it was possible for students to partake in this project in substitution for a work placement. HoD expressed interest in expanding the outcome of this intervention to more schools in the locality in future.

This initial groundwork helped ensure a smooth transition into the co-design process. It was also agreed during this phase that the Change Laboratory workshops would be conducted online, to accommodate scheduling constraints and maximise participation across both institutions. The decision to hold sessions online was jointly made during early planning conversations and was driven by several pragmatic considerations. For university participants, the online format reduced the need for timetable adjustments or travel, making it easier for management, faculty and students to attend sessions during the semester. From the school's perspective, it allowed teachers to join from their own classrooms or offices during quieter periods of the school day, thereby minimising disruption to teaching responsibilities. Although I initially had some reservations about how the dynamics of expansive learning might be affected in an online format, particularly the potential limitations on dialogue and artefact use, I recognised that digital platforms could still enable productive interaction when carefully structured. Therefore, the online format was seen as the most viable option to facilitate collaboration between busy participants across two institutions during an ongoing pandemic recovery period.

4.6.2 Design of sessions

Engeström's expansive learning cycle (as described in Section 3.4), consists of seven learning actions beginning with questioning right through to consolidation of new practices. This is a project that primarily focuses on the first four actions of the expansive learning cycle, questioning, analysis, modelling and examination, and later focusing on reflection, as established in Chapter 1. The Change Laboratory sessions were planned and designed to guide participants through these four stages beginning with questioning and progressing through analysis, modelling and examination. Each session was designed to engage participants with the use of double stimulation and conducted via video conferencing, which influenced the choice of digital tools and collaborative methods used throughout. Presented in Table 4.2 is an overview of the initial plan for each session and how I thought they may go, prior to them actually commencing. The schedule and duration of sessions were shared with participants before the first session.

A Change Laboratory does not always unfold as planned, ideally due to participants exerting their agency and deviating from the researchers plan (Bligh and Flood, 2015), and so when I was designing each session, I expected they were likely to diverge gradually over time. I started out by designing all six sessions with the understanding that my designs may need to be adapted as we progressed through the sessions and based on the analysis of session outcomes.

Table 4.2: Overview of planned design for Change Laboratory sessions

Session no. & date	**Expansive Learning Action**	**First-stimulus / Tasks**	**Second-stimulus**	**Mirror-data**	**Emerging Tools / Ideas (Second Stimuli – 3rd Surface)**
Session one 04/03/2022 90 mins	Questioning and Analysis (historical)	**Task 1A**: Experiences, passions, and opinions about outreach and girls in computing. **Task 1B**: Past outreach by university and school.	Timeline mapping tools and Notion page. Invitation to list and visualise activities.	Gender breakdown stats; podcast audio clip.	Timeline of previous recruitment efforts; initial vision statements for outreach goals.
Session two 11/03/2022 90 mins	Analysis (empirical)	**Task 2A**: Identify current outreach and school computing provision. Explore their structure and purpose.	Blank Activity System diagrams for school and university; Notion page for ideas.	Ongoing mirror discussion from participants; AS diagram explanation.	Shared activity systems mapped by participants; recognition of contradictions (e.g., missing 2nd year computing).
Session three 25/03/2022 90 mins	Modelling	**Task 3A**: Propose future school computing activities. **Task 3B**: Complete new AS diagram for outreach initiative.	Blank two-system diagram; wiki page for needs and actions.	Outputs from previous sessions.	List of school needs; first draft of outreach curriculum (titles, delivery ideas).
Session four 01/04/2022 90 mins	Modelling	**Task 4A:** Review and assess proposed components of the outreach model.	Wiki page feedback tool; collaborative feasibility discussion.	AS model showing tensions and contradictions.	Refined joint activity system; draft component list for outreach (timeline, mentor roles).
Session five 29/04/2022 90 mins	Examination	**Task 5A:** Are we near a finalised initiative? **Task 5B:** How can we tailor it to attract girls?	Wiki page with proposed final solution.	AS model and visual strategies from literature.	Revised initiative incorporating gender-focused elements (rebranded subject titles, role model integration).
Session six 13/05/2022 90 mins	Process Reflection	**Task 6A:** Reflect on how well the design meets stakeholder needs.	Feedback recorded on Notion.	Final outreach model as defined in Session 5.	Reflections on sustainability and implementation; shared priorities for future action.

4.6.3 Scope and timing of sessions

Bligh and Flood suggest that a Change Laboratory research-intervention needs an adequate amount of sessions and necessary work in between those sessions to fully consider the expansive learning actions. They also indicate that "Sessions need to take place sufficiently frequently that momentum is maintained for undertaking tasks or generating new evidence between sessions" (p. 156). Virkkunen & Newnham (2013) recommend 5-12 sessions each of around 2 hours' duration and that they should take place on a weekly basis (p. 66).

I chose to conduct 6 Change Laboratory sessions of 90-minute duration (not including the initial meeting in the computing department discussed in 4.6.1) as I anticipated six as an adequate number of sessions to fully consider the five expansive learning actions covered in this project.

I scheduled the sessions over a 3 month period between March and May 2022. Participants were urged to commit to all sessions, or as many as possible. All sessions were scheduled for Friday afternoons starting at 1.15pm. This date and time was identified during my school visit, discussed in section 4.6.1, as the only suitable time for teachers to attend sessions based on the timetable for their teaching duties. It is for this reason that one of the criteria when recruiting and selecting participants from the university included availability on Friday afternoons. The timeframe agreed with the school for the sessions was March to May before the summer holidays commenced (with the aim of implementing the new outreach initiative in the school the following September). These months presented me with a challenge as several Fridays in these months are national public holidays in Ireland, including the new St. Patrick’s day public holiday on March 18th and Easter break in April as highlighted in blue in Figure 4.1.

Figure 4.1: Academic calendar with sessions dates (orange) and holidays (blue).

Therefore the scheduling of sessions on Friday afternoons over that three month period was restrictive as I needed to take into consideration participant availability and to allow adequate time to complete necessary work in-between sessions. Upon consideration of the final dates chosen for sessions, I was confident that the schedule would be effective, with an adequate time between sessions to keep momentum going while allowing participants to fully consider things in relation to the expansive learning actions. The preliminary dates of sessions illustrating the number of weeks in-between sessions are illustrated in Figure 4.2.

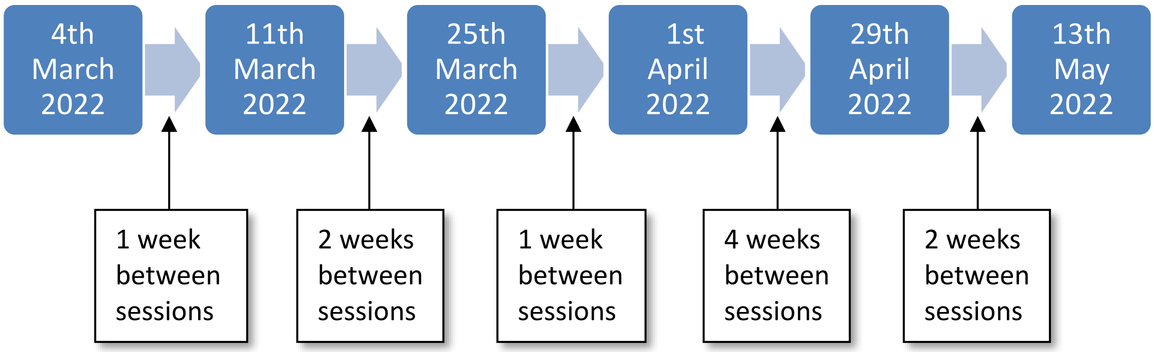


Figure 4.2: Timeline of scheduled sessions, highlighting intervals between sessions

As described in Chapter 1, we always knew that we could only schedule six workshops in the time period and that more workshops would maybe come after summer or after some period of implementation. So for the final workshop which was scheduled close to summer break, I wanted to end with a moment of process reflection, because that will give a good impetus even for the later projects.

4.6.4 Conducting the sessions

The Change Laboratory is a well-established method in settings in which the participants are physically present. For such settings Virkkunen & Newnham (2013) recommend the typical format for a Change Laboratory illustrated in Figure 4.3. It combines a number of roles such as practitioners, scribe, minutes keeper and researcher-interventionists with a number of items such as video camcorder, archives, and PC. The 3 × 3 set of surfaces are an important tool in the Change Laboratory. These are used to represent past, present and future activity.

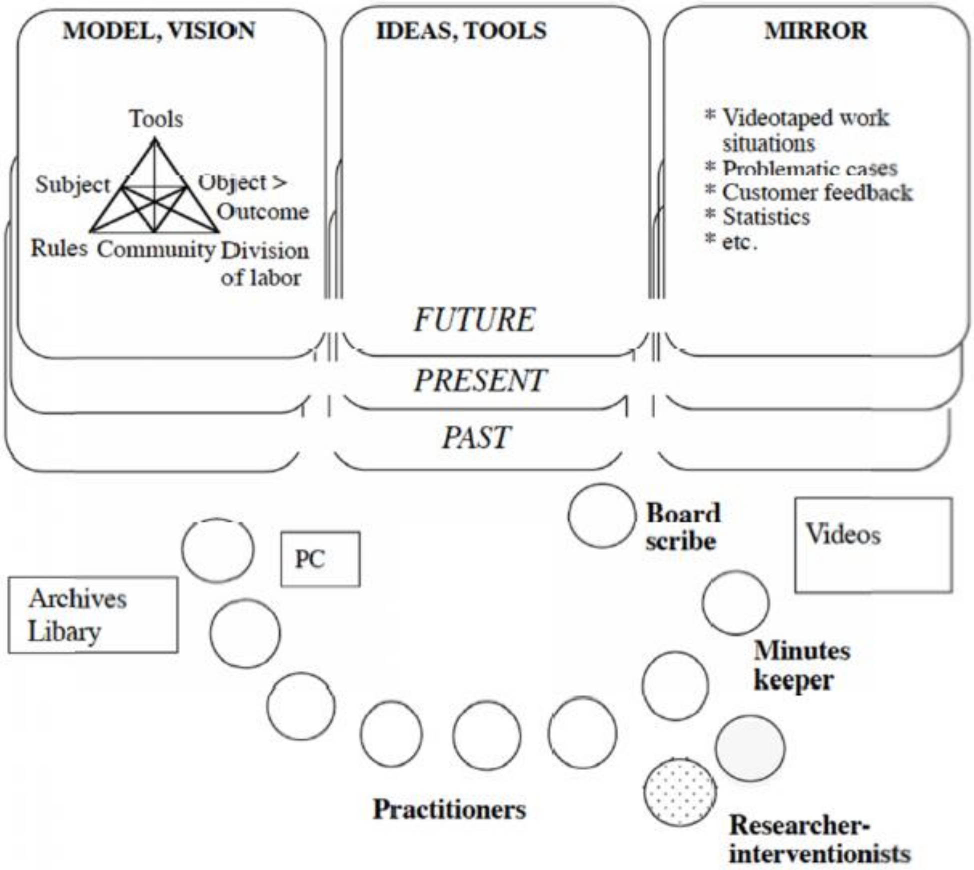


Figure 4.3: Prototypical layout and instruments for a Change Laboratory session taken from Virkkunen & Newnham 2013, adapted from Engeström et al. 1996 p.11

4.6.4.1 Setup for conducting sessions online

This Change Laboratory intervention was conducted entirely online. This decision was shaped by a number of contextual factors. Firstly, the university and school are in different locations, and coordinating face-to-face sessions would have posed significant logistical challenges for participants from both institutions. Secondly, scheduling sessions that suited participants' teaching and institutional commitments was more feasible through remote participation. As highlighted by (Spante *et al.*, 2023), online Change Laboratories offer an inclusive, flexible format that accommodates diverse participant needs, including care responsibilities, work schedules, and geographical separation. Drawing from this wider community of practice, of which I was a contributing member, the decision to conduct the CL online was both pragmatic and consistent with emerging methodological approaches that support expansive learning in digitally mediated contexts.

Microsoft Teams was chosen to co-ordinate and manage sessions, as this platform has recording functionality, the option to create breakout groups, conversation threads, chat, and documentation sharing. This project made use of all of these features, the outcome of which was mirror-data which I made available as resources to participants (as discussed in section 3.5) that could be returned to in subsequent sessions. Figure 4.4. shows a screenshot of MS Teams being used to conduct session one.

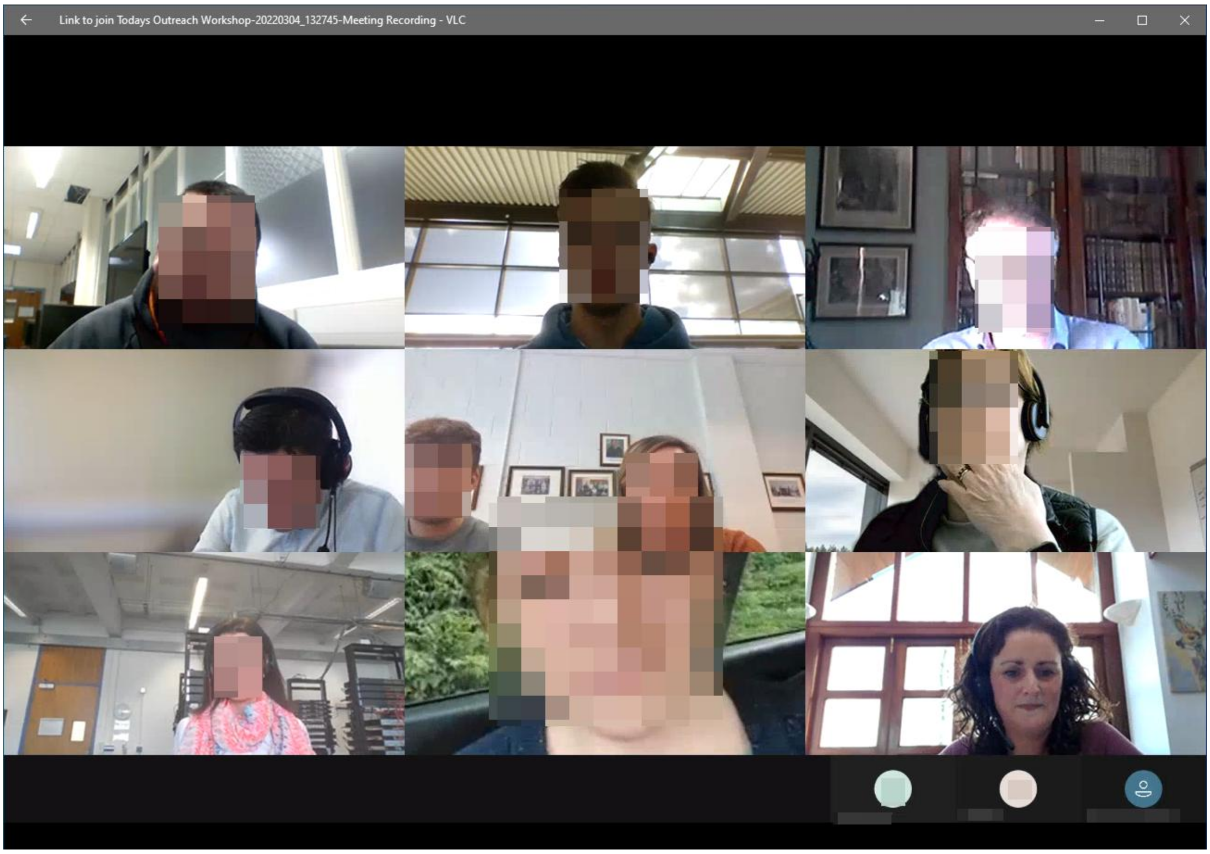


Figure 4.4: Screenshot illustrating the use of MS Teams to conduct session one (anonymised)

Unlike the typical format shown in Figure 4.3, which has the 3 x 3 surfaces, this is not feasible in an online setting. In comparison, the best that I could do to approximate this kind of setup was as follows. During sessions, data was presented to all participants synchronously, one slide or Notion wiki page at any given time, occasionally switching between screens when needed or referring participants to look at a specific resource at times. When I or another participant recorded notes or added answers to lists, all attendees in the Teams call could see the list being generated. At times, participants were split into breakout groups, and so participants could only see the data presented within that group. Participants had access to all resources and therefore may also have had other information open on another screen for their use. This is what I was hoping would happen, however in an online venue such as this, we can't completely control exactly what participants see and do.

An online tool called Notion, shown in Figure 4.5, was used as the project's shared workspace. Notion is a collaboration platform that all participants had full access to for the duration of the project. Examples of how I used Notion are provided in subsequent sections of this Chapter. Additional information on how I used this platform to project manage this research-intervention can be found in a separate resource I authored titled *Project Management of an Online Change Laboratory using Notion* (Redmond, 2023).

Figure 4.5: Screenshot of anonymised Notion workspace used to manage Change Laboratory

4.6.4.2 Researcher-interventionist role during sessions

I carried out this project as a sole researcher-interventionist and therefore facilitated all aspects of sessions including: video recording, note taking, creating and recording individual breakout rooms, presenting content and making collaboration tools available to participants during tasks. Following each session, I also managed the sharing of video recordings, transcripts and any artefacts created during sessions with all participants.

4.6.5 Design of tasks

Task-design is central to the Change Laboratory approach, since tasks are the key method of knowledge production, and the tasks for each session of this study was designed using the principle of double-stimulation as outlined in Chapter 3. As researcher-interventionist I designed the tasks based upon the five expansive learning actions which are the focus of this project - questioning, analysis, modelling, examination, and reflection as established since Chapter 1. I planned activities to encourage participants to question practice, discuss problems and develop a new model by giving them the tools to do so. For example when planning for session one, I began by thinking about how to design the first task that would get people to *question* current practices in their own context surrounding female participation in computer science in their classrooms. This resulted in the questions I asked in Task 1B as illustrated in Table 4.2. In line with the first expansive learning action, I wanted to *question* participants. My plan was for participants to raise and discuss issues and conflicts experienced in their context to highlight to participants the problem of female underrepresentation in computer science in general and locally, and to learn from the school their current computing offerings through questioning. Then moving on to opening up discussions with the group so that they could begin to realise the object of this project and what both the computing department and the school would collectively like to achieve from it.

In order to do this effectively, my aim was to integrate key statistics, documents, media, anything which would encourage participants on. This is what is meant by mirror-data, and so I began contacting relevant stakeholders who had access to first-year recruitment figures in the computing department and the main ICT teacher in the school who could provide data on student figures studying computing subjects. In conjunction with this I scanned the web looking for resources such as reports, podcasts, videos that would highlight the issue at a wider scale and the impact outreach can make to females during their school years. I also needed to decide how I would organise participants during the session (e.g., by group(s) or individuals).

My plan in this section is not to describe the intended designs of all sessions but to provide explanations of my thought and planning process, the terminology used during task design and to provide some examples. Table 4.3 illustrates the format used when designing session one and the task for the session with any corresponding concepts which will be expanded on now.

Table 4.3: Design of session one showing Task1B which was designed around questioning

	SESSION ONE 04.03.2022 **(1)**			
	Expansive learning action: Questioning **(2)**			
	First-stimuli (3)	**Second-stimuli (4)**	**Mirror-data (5)**	**Social organisation (6)**
TASK 1A	Introduce participants, project and problem trying to change.		Introductory material with key points about project and process. Visual material illustrating low enrolment of females in general.	Group (14)
TASK 1B (7)	What are your experiences surrounding the number of female students in your classes? What are your motivations for joining this project? What do you think a Computing Outreach programme for today's secondary school students needs to be effective?	Participant answers and discussions recorded on Notion and made available to all to serve as mirror-data.	Statistics with gender breakdown of students studying computing in both contexts presented. Audio snippet to demonstrate and motivate how outreach can make a difference.	Addressed as individuals
	Documentation, discussion and Recording (8)	Use Notion workspace to record discussions and ideas. Use MS Teams to host and record session.		

To aid in the description of the main headings of Table 4.3, I have numbered them 1 to 8 and these can be explained as follows:

(1) *Session One 04.03.2022* specifies the session number and the date the session occurred.

(2) *Expansive learning action* refers to the phase of the expansive learning cycle (Engeström, 1999) that this session and task are designed around which in this session was questioning.

(3) *First-stimuli* is the task specification which participants were given the goal of addressing. Following an introduction to the project and an overview of the problem, the first-stimulus of Task 1B (7) involved asking participants a set of questions. The intention of these questions was to make them conscious of a problem which they construct, supported by mirror-data (explained in number 5).

(4) *Second-stimuli* are the analytical tools or methods that were used to address the first-stimulus task. As shown in Task 1B, second-stimuli are the answers that are recorded on

new lists generated from participant answers to first-stimuli questions. The generated lists are then made available to the team on Notion to server as mirror-data.

(5) *Mirror-data* are the materials that were used to represent practice problems and contradictory situations to participants. Examples of the mirror-data used in the sample task provided in Table 4.3 can be seen in section 4.6.5.3 below.

(6) *Social organisation* refers to the flow of participant work, considering moments of whole group, small group, or individual working. In the sample task provided in Table 4.2, participants were to address Task1B individually, while participants could be divided into groups to address tasks in subsequent sessions.

(7) *Task 1B* refers to the name of the task. The 1 signifying the session number and B signifying the order of tasks for that session.

(8) *Documentation, discussion and recording* refers to how individuals or sub-groups externalise their thinking for discussion with others and how those discussions are recorded to be re-used later. My plan was for participants when collaboratively working on Task1B to use Notion to record discussions and ideas in real-time. The session would be hosted and recorded online using MS Teams. All of which would form part of the data collection to be examined.

In Chapter 5, I will describe all tasks from each session and describe how they unfolded in a similar format as done with Table 4.3. Examples of first-stimuli, second-stimuli and mirror-data will now be shown.

4.6.5.1 First-stimuli

Figure 4.6 illustrates an example of a task I prepared on Notion ahead of session two. This includes four questions based on the historical analysis and empirical analysis expansive learning actions. This resource is accessible to all participants, and ready for population with answers from participants. Similar to this task, I prepared all other tasks on Notion in a similar fashion ahead of each workshop, making them readily available to make visible to participants when required (Redmond, 2023).

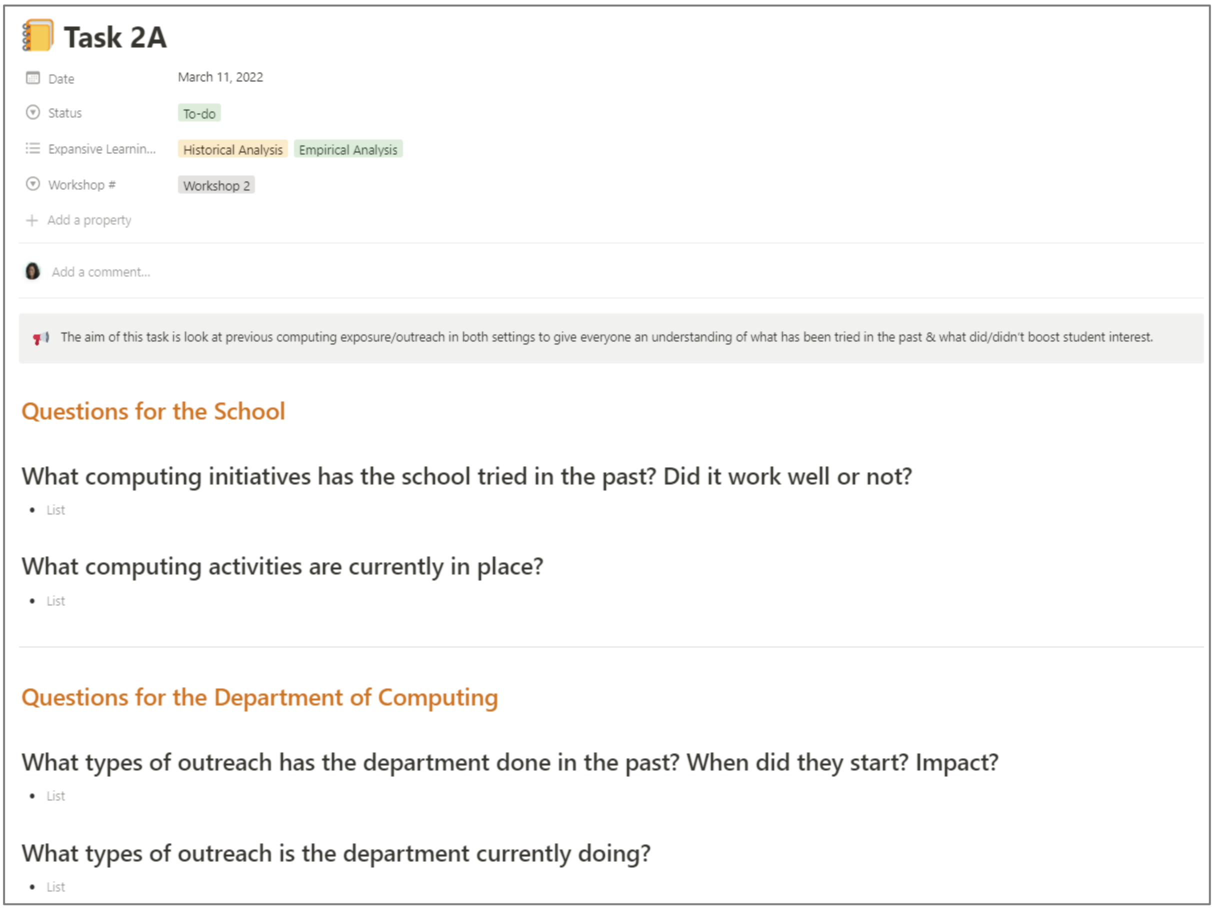


Figure 4.6: Example of a task I prepared ahead of session two on Notion.

4.6.5.2 Second-stimuli

Activity System worksheets, as shown in Figure 4.7, were created ahead of session two, ready for completion by participants during the session.

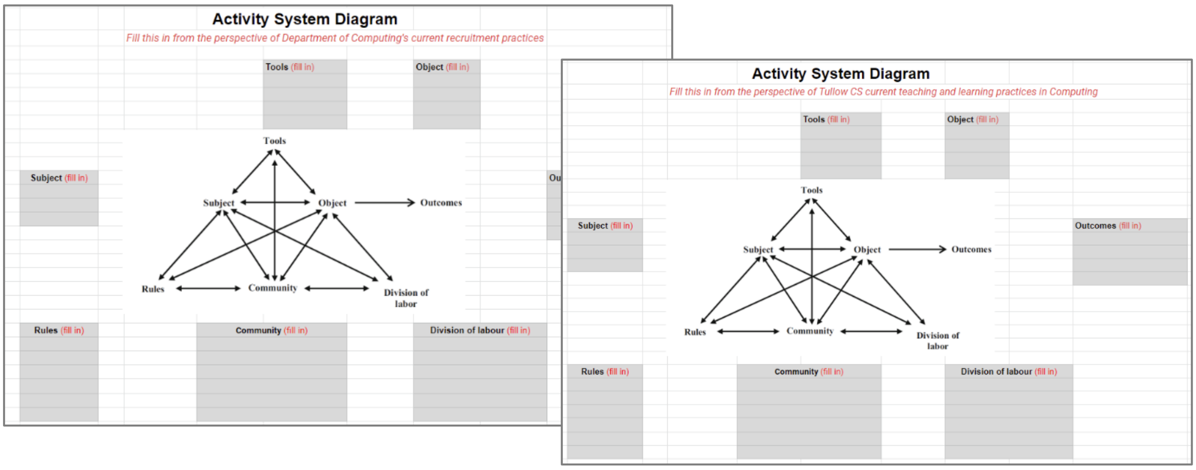


Figure 4.7: Sample Activity System diagrams prior to completion

4.6.5.3 *Mirror-data*

The purpose of generating mirror-data for the first Change Laboratory session was to create a shared point of reflection that would surface the existing contradictions within participants current practices. In line with the expansive learning cycle, mirror-data acts as a stimulus for the questioning action by confronting participants with representations of their own activity. My intention in selecting and curating these artefacts was twofold, first to reveal both local and broader gender disparities in computing education and second, to provoke critical discussion on the effects of outreach, or the lack thereof, on young peoples educational choices.

Prior to session one, I gathered gendered statistics on student enrolments in computing across Europe and from both the university computing department and the school participating in my study. These statistics, shown in Figure 4.8, were selected to highlight the ongoing gender imbalance in computer science at the undergraduate level, across Europe and more locally in this projects university over the past five years. I also included gender-specific statistics from the schools own student enrolment data for subjects that align with computing or digital skills over the previous two years. The intention here was to identify local issues and foreground the immediate context in which participants were working.

A look at Current Student Figures

At the Bachelor level in Ireland and across Europe - **80% or more** of the students enrolling or graduating in Informatics Bachelor programs **are male**.

Source: COST Action CA19122 EUROPEAN NETWORK FOR GENDER BALANCE IN INFORMATICS (EUGAIN), March 2020

This under-representation of females in Informatics higher education in Europe and further afield is a long-standing problem with no significant progress observed over the past decade or more.

Looking specifically at our own contexts:

DEPARTMENT OF COMPUTING:

Percentage Of Female Students Enrolled On Undergraduate Courses

Academic Year	% Females
2016/17	8%
2017/18	9%
2018/19	12%
2019/20	14%
2020/21	15%

SCHOOL:

Number Of Students on Computing Subjects currently available

First Year Computing (estimates)	Male	Female	TOTAL
2020/2021	81	81	162
2021/2022	76	76	152

Transition Year Coding	Male	Female	TOTAL
2020/2021			
2021/2022	13	8	21

Leaving Cert Computer Science	Male	Female	TOTAL
2020/2021	15	12	27
2021/2022	16	4	20

Figure 4.8: Visual material designed for session one during questioning activity (anonymised)

In preparation for session one, I also sourced a relevant podcast and extracted a short snippet of it for use during the questioning action. The audio snippet was of a female describing a personal experience of hers where she recalls a moment during her time in secondary school where a visit from an undergraduate computing student to the school to talk to her class was all it took in helping her decide to pursue computing at undergraduate level. I chose to use this artefact to demonstrate to participants the beneficial effects that outreach experiences in secondary school can have on female students. The podcast was uploaded and shared on Notion as shown in Figure 4.9.

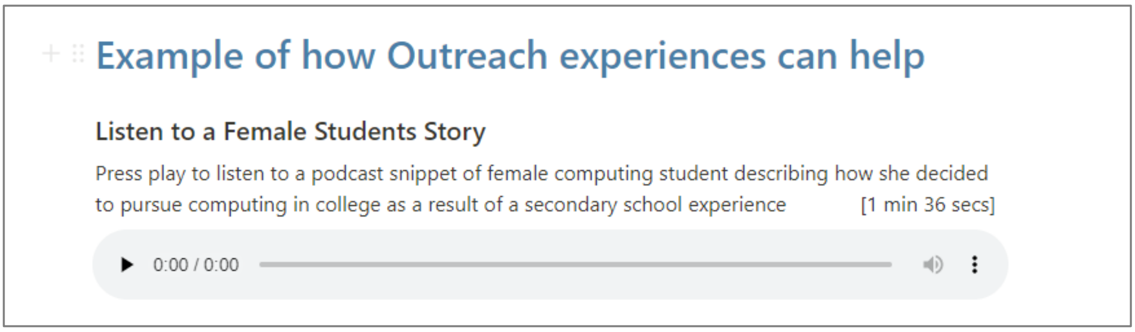


Figure 4.9: Podcast artefact designed for CL session 1 during questioning activity

4.6.6 Sharing of session recordings, notes and agendas

Use of Notion was found to be beneficial in storing notes and artefacts from one centralised system which all participants were given access to. This made designing tasks and preparing for subsequent sessions more manageable. For example, during each session, participant generated lists and significant ideas or considerations were recorded using Notion. Following each session I reviewed and transcribed the session, taking note of the key points made and uploading them to Notion also. An example of a shared space on the platform containing participants answers to Task 1B can be seen in Figure 4.10.

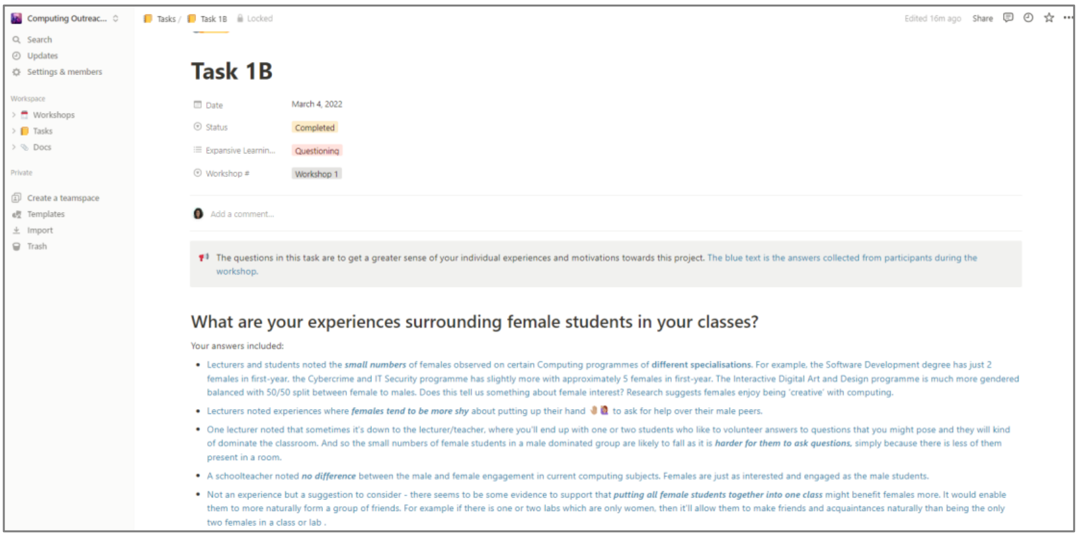


Figure 4.10: Shared Notion page: Participants' Task 1B, Q1 responses from session one.

Video recordings of all sessions were available to all participants on the projects Microsoft Teams channel as seen in Figure 4.11.

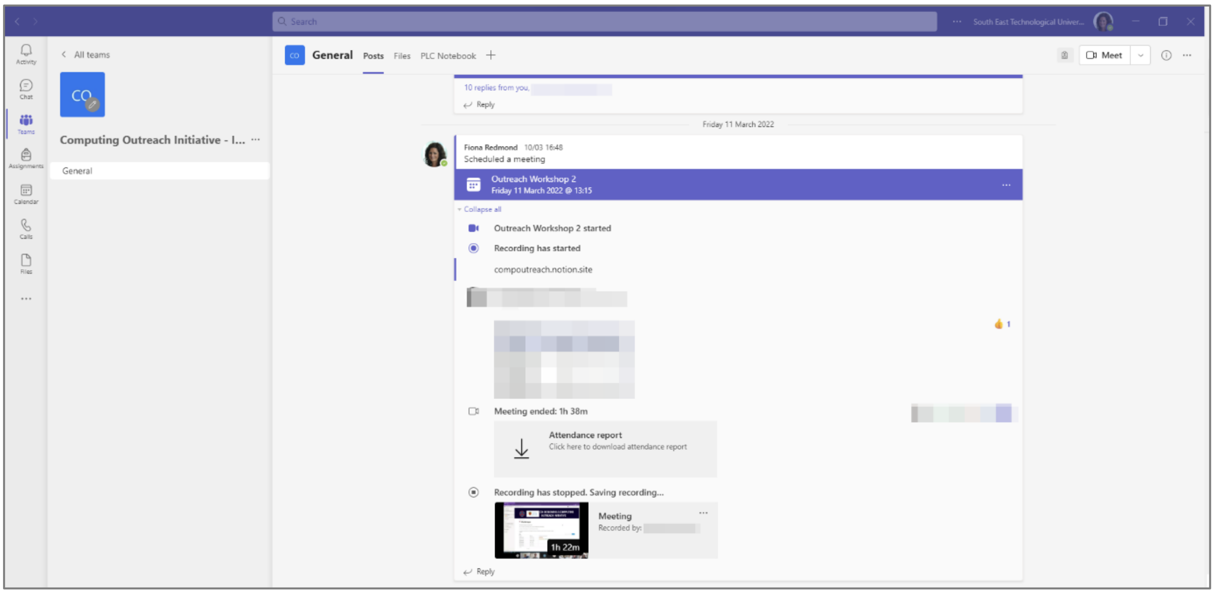


Figure 4.11: Teams channel screenshot showing availability of session recording (anonymised)

One day prior to each session, an email was sent to all participants with a reminder of the upcoming session and a link to join the next session, along with the agenda and when necessary a link to the Notion workspace.

4.7 Data Collection Methods

4.7.1 Session recordings and transcripts

The primary data source of this study are the video recordings and transcripts of the six sessions. As soon as all participants attending had logged on to the session on MS Teams, the recording began and continued until the session ended. On occasion there was a delay in starting the recording of a session or when participants were sent into breakout rooms. However on those occasions, the researcher or participants in that group were taking notes and could be shared following the session.

A transcription tool called Otter, as illustrated in Figure 4.12, was used to transcribe each session. I reviewed these automatically generated transcriptions to make any necessary corrections and used these transcriptions when writing up notes about that session. Those notes were then added to Notion so it was accessible to all participants to review.

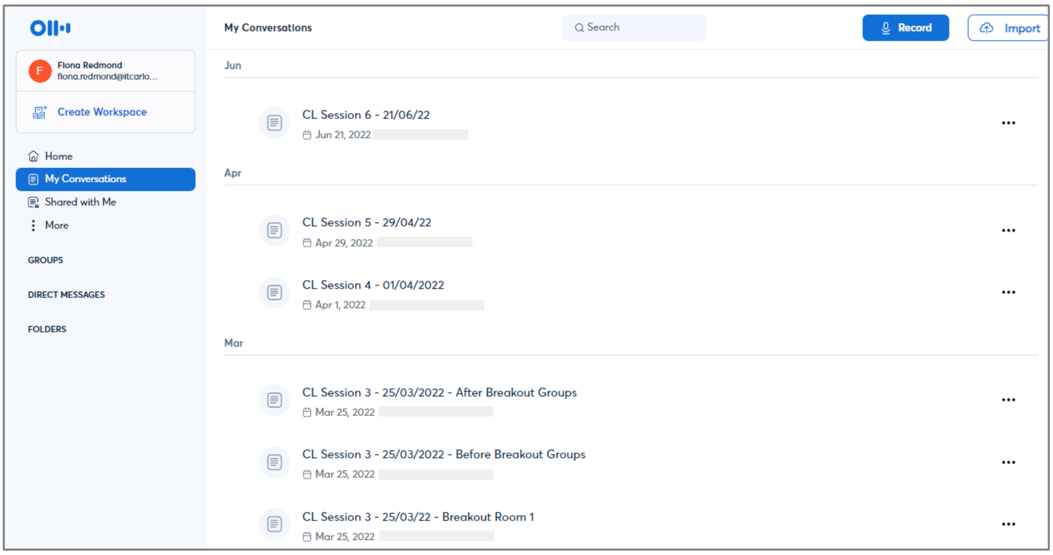


Figure 4.12: Otter transcription screenshot (anonymised)

An uncorrected excerpt from session one transcript generated by Otter is shown in Figure 4.13. The excerpt is from the start of session one where I asked each participant to introduce themselves to the group stating their name, their role and something else about themselves.

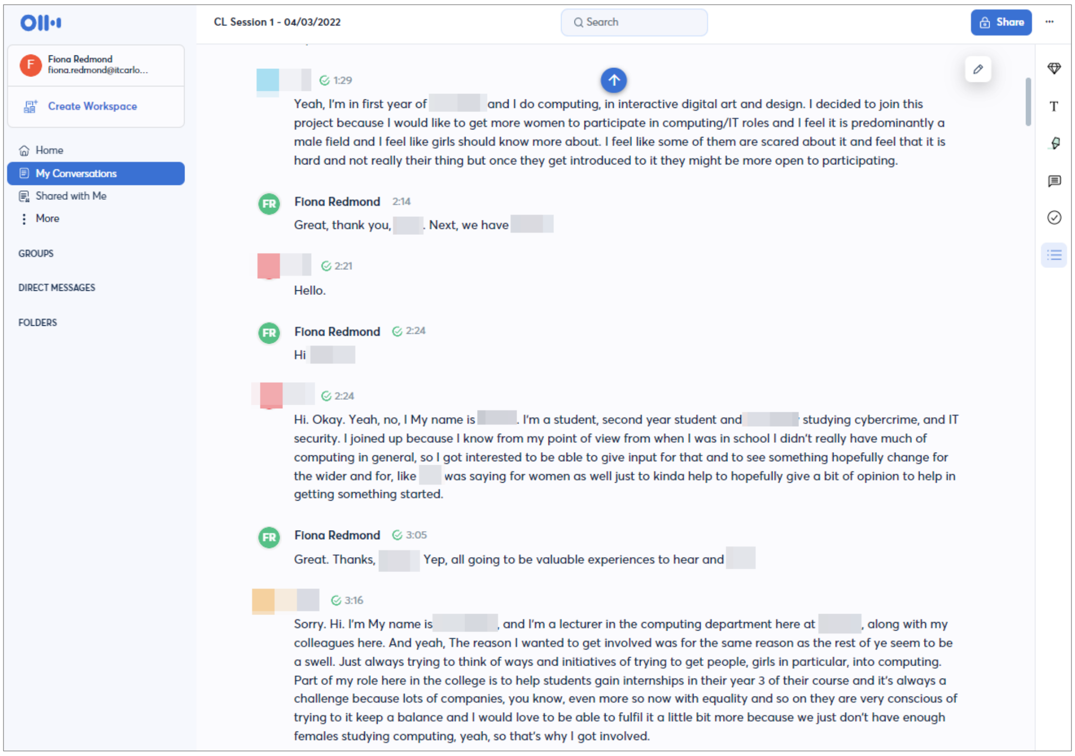


Figure 4.13: Excerpt from Session One transcript on Otter (anonymised)

4.7.2 Artefacts

A variety of artefacts were created by participants throughout the series of CL sessions, all of which were created using, or uploaded to, Notion and accessible to all participants. This section provides examples of artefact which were created during sessions and subsequently analysed.

4.7.2.1 Participant generated lists

Throughout the session, typical questioning tasks resulted in participants noting their answers using a bullet point style list. An example of one of these participant generated lists is shown earlier in Figure 4.10.

4.7.2.2 Activity system diagrams

Activity System diagrams, shown in Figure 4.14, were completed by participants in session two.

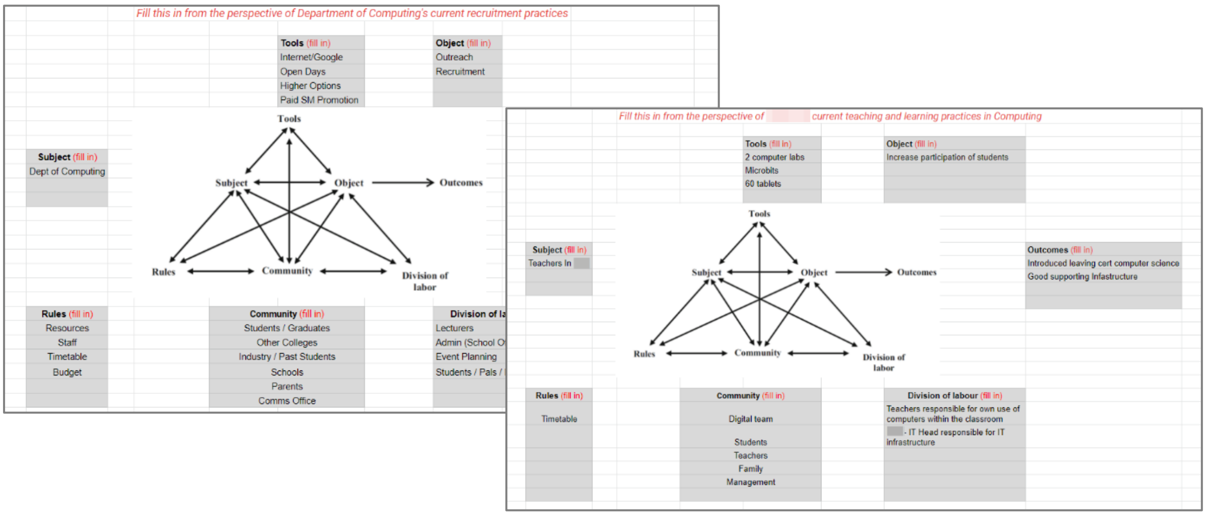


Figure 4.14: Sample Activity System diagrams prior to completion (anonymised)

4.7.2.3 Timelines

Figure 4.15 shows an example of a timeline of outreach activities carried out by the department of computing, based on information shared by participants during a session and shared for review.

Timeline of Department of Computing's outreach activities

Date	Name	Details
2008	Lecturer visits to schools	• promoting computing courses, Q&A • sporadic times throughout the academic year • Difficult to gauge its impact on enrolments
2010	GameJam	• Participation restricted to UG students • Age Restrictions: 18+ only. Majority male.
2010	Technology Summer Camps	• Open to senior cycle students starting from TY. i.e. those sitting the Leaving Certificate the following two years. • Web Design (HTML and CSS), Programming, Hardware and Networking ◦ create apps, develop an interactive web site, build a computer network, assemble computer hardware • 1 week camp every June until 2021 (structure changing in 2022 - possible 2 x 2-day camps of different focus e.g. robotics, gaming and creative camps) • Approximately 20 - 30 places • Supported by the Higher Education Authority • Averaged 84% male between 2013-2018 • Is there data to show how many go on to study computing?
2013	Women in Computing & Engineering Seminar	• Annual event on campus • Transition year students • female-only schools invited? • Q&A with panel of UG/PG engineering and computing students
2014	Coder Dojo	• Started originally in a local school in 2012 • open to 8-16 year olds. • 2 hr classes on Tuesday evenings from 6:30pm to 8:30pm (Feb - March) • teaches kids coding through Scratch, HTML and Project ◦ learn how to code, develop websites, apps, programs, games and more. • Undergraduate computing students volunteer to help • male/female ratio? • Is there data to show how many go on to study computing?
2017	Women in Technology Society	• open to all UG/PG students (not just computing) • networking and support ◦ coffee mornings, company visits, attending career talks and more.

Figure 4.15: Researcher-generated outreach timeline based on participants' accounts..

4.7.2.4 Diagrams

Figure 4.16 shows a sample of diagrams developed by participants during session three.

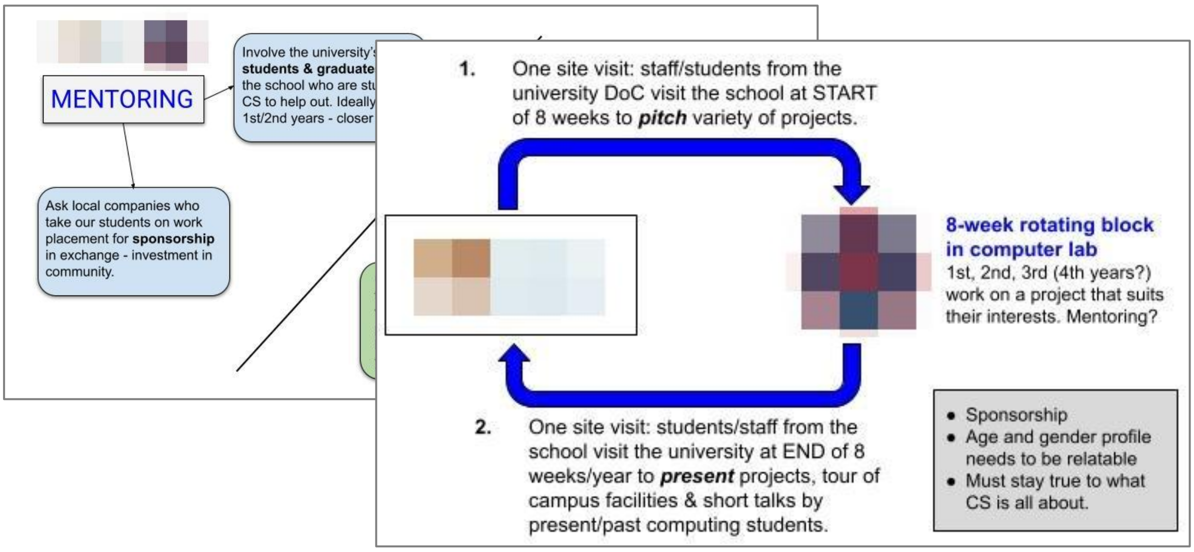


Figure 4.16: Sample diagrams developed by participants during session three

4.7.3 Reflective research diary

In recognition of my position as insider-researcher (section 4.4), I maintained a reflective research diary, which is common practice in qualitative research. Throughout the different stages of the project, I recorded my experiences, thoughts and observations on what I felt worked well and what didn't – for example, if mirror-data were effective at stimulating discussions of the problems identified in both institutions, or if they were supportive of the expansive learning action that that session was designed around. Figure 4.17 shows a sample of an entry in my research diary directly following workshop one.

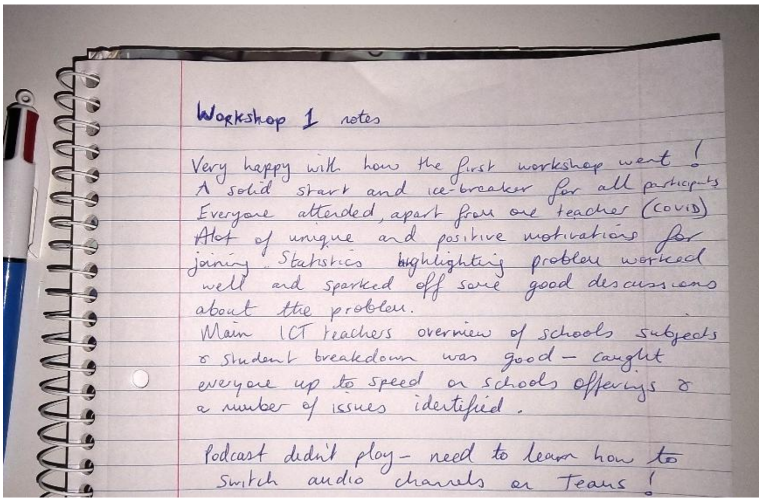


Figure 4.17: Sample entry in Research Diary reflecting on workshop one

4.8 Data Analysis

In line with the overarching aim of this research, to co-design a contextualised outreach initiative to attract females into computer science, while simultaneously generating new knowledge about the collaborative design process in a university-school partnership (as outlined in Section 4.2). The data analysis procedures were designed to trace and understand both the outcomes of the intervention and the learning processes that led to them. This study was not solely focused on developing a practical outreach initiative, it also aimed to produce conceptual and empirical insights into how such an initiative can emerge through a Change Laboratory process.

Change Laboratory research-interventions typically generate a large volume of diverse data, including video recordings, session notes and minutes, flip-chart materials, and full transcripts (Scahill and Bligh, 2022). In this project, all these data types were utilised, along with additional reflections recorded in my reflective research diary (see Section 4.7.3). The analysis aimed to identify and interpret data relevant to the study's three research questions:

- **RQ1**: What does the design of a context-specific outreach initiative aimed at increasing female participation in computer science higher education look like when collaboratively developed by multiple stakeholders?
- **RQ2**: What processes and interactions shape the collaborative development of a bespoke outreach initiative aimed at increasing female participation in computer science higher education?
- **RQ3**: What do the outcomes and processes of designing a context-specific outreach initiative reveal about the potentialities and constraints within the local context for increasing female participation in computer science higher education?

The findings presented in Chapter 6 are the result of a three stage analysis process: intra-session, inter-session and post-intervention analysis, as outlined by Scahill and Bligh (2022) in their discussion of Change Laboratory research-interventions in higher education.

4.8.1 Intra-session analysis

This stage of analysis took place *during each session,* as the intervention unfolded and new data were generated. Intra-session analysis was a collaborative activity conducted by both participants and the researcher-interventionist. These real-time reflections helped shape the direction and pacing of each session and frequently resulted in the adjustment of session plans and tasks.

Participants engaged with the activity system model to structure their thinking and to frame their reflections. For instance, in a session dedicated to identifying tensions within existing outreach practices, participants mapped institutional roles, norms and constraints by discussing the *rules* and *division of labour* elements of the activity system. This helped them surface contradictions between the way outreach was organised and its intended impact.

As participants worked on structured tasks, such as historical analysis (see Figure 5.18), the researcher-interventionist scaffolded engagement by clarifying tasks, prompting with mirror-data, and reorienting activities to support expansive learning actions (e.g., questioning, analysing, modelling). This stage of analysis was instrumental in addressing RQ2, as it captured the real-time emergence of collaborative processes and interactions shaping the design.

4.8.2 Inter-session analysis

Inter-session analysis occurred *between sessions* and focused on reviewing the data produced in each session. These included video recordings, transcripts, researcher diary entries and artefacts. The aim was to identify moments and outputs that were especially relevant for carrying forward into future sessions and to support continuity in the collaborative process.

As researcher-interventionist, I transcribed the sessions (see Section 4.7.1), reviewed the video recordings alongside field notes, and composed workshop summaries documenting decisions, emerging themes and areas of tension. These were shared with participants on the collaborative Notion workspace (see Figure 4.9), where all participants had editing rights to amend, annotate, or comment on summaries. Participants were encouraged to engage with this material before and during each subsequent session.

This analysis shaped the design of subsequent tasks, ensured accurate representation of participant input, and supported the creation of new mirror-data where needed. The ongoing dialogue between sessions was essential in enabling expansive learning across the full cycle and maintaining participant engagement.

This stage of analysis contributed to both RQ2 and RQ3, as it revealed how participants navigated local opportunities and constraints while shaping the design collaboratively, often identifying recurring barriers and refining features accordingly.

4.8.3 Post-intervention analysis

This final stage of analysis was conducted *after the completion of all six sessions* and involved a comprehensive review of the full dataset, including transcripts, session recordings, artefacts and reflective notes. The goal was to develop a coherent account of how the outreach initiative was designed, and to understand which elements emerged in response to specific contextual challenges and contradictions.

This phase used a combination of deductive and inductive coding strategies:

- A deductive approach, informed by the activity system model (see Chapter 3), was used to track how participants discussed each system element (e.g., subject, rules, division of labour, tools, community, object) across sessions. For example, I analysed how participants' discussions about the division of labour shifted from initial critiques to eventual design proposals. This mapping process allowed me to trace the evolution of the shared object and surfaced moments of expansive learning, where new tools, roles, or rules were proposed to resolve contradictions.

- An inductive open coding approach was applied to session six transcripts and feedback collected via email from participants who could not attend. This analysis aimed to identify how participants articulated and made sense of the proposed design, including the contextual challenges it addressed, the assumptions underlying its components, and any anticipated barriers or enablers to implementation. These insights contributed to understanding both the shape of the outreach initiative (RQ1) and the local conditions affecting its design (RQ3).

This post-intervention analysis underpins the findings presented in Chapter 6. It enabled a detailed reconstruction of how the proposed outreach initiative evolved, from the identification of contradictions, to collective modelling, and ultimately to the articulation of a sustained, context-specific response to gender imbalance in computer science in higher education.

4.9 Ethics

Ethical approval for this research-intervention project was sought and obtained from both Lancaster University and South East Technological University (SETU) Carlow campus. The research was conducted in accordance with the ethical frameworks of both institutions. All participants in the research-intervention were provided with detailed participant information sheets prior to taking part, and informed consent was obtained via signed consent forms. Participants were advised that participation was voluntary, and that they could withdraw from the project at any point without having to provide a reason. All participants also consented to the Change Laboratory (CL) sessions being video-recorded and transcribed. In line with standard ethical practice, pseudonyms have been used in place of participants' names in the thesis and any published work.

The research topic, female participation in computer science, is both socially and politically charged. It involves deeply held views about gender balance, identity access to opportunity, and systemic bias. The Change Laboratory methodology is dialogical and collective in nature, and discussions were intentionally designed to surface tensions, contradictions, and different perspectives. As Nuttall (2022) notes, ethical facilitation in CLs extends beyond procedural safeguards to include creating a space where participants can confront and work through contradictions in ways that are both safe and productive. Care was therefore taken throughout to foster an open, respectful, and non-judgemental environment. Ground rules for discussion were co-developed during the early sessions and revisited as necessary to ensure that all voices were heard, and that potentially contentious issues could be raised and explored constructively.

As the facilitator and primary researcher, I was mindful of the relational ethics involved in co-design processes. I was known to many of the participants prior to the study, both through my role as an academic in SETU and through institutional collaboration with the school. This insider status brought both opportunities and responsibilities. As Miles (2022) observes, insider-researchers in CLs must navigate a dual position that affords trust and access but also risks reinforcing existing hierarchies or unintentionally shaping outcomes. This required ongoing reflexivity to ensure that my position did not silence or bias others' contributions. I took deliberate steps to support a facilitative, rather than directive, stance, such as posing open questions, revisiting participants' own ideas in later sessions, and foregrounding their language and framing shared artefacts.

While formal consent procedures were followed, ethical responsibility was also understood as ongoing, situated, and relational. Decisions about how data would be represented, which insights would be shared back to participants, and how the outreach initiative would be documented and carried forward were all treated as part of an evolving ethical dialogue. Participants were kept informed of the research process and offered opportunities to review the outputs of the intervention. These choices reflect a commitment to ethical practice not only in procedural terms, but as a central feature of the Change Laboratory's participatory and expansive approach to learning and change (Nuttall, 2022).

4.10 Limitations and Challenges

Research projects are regularly shaped by limitations and challenges that must be acknowledged, and it is important to address these at this point. One of the initial challenges of this project was that it had to respond to both the operational needs of the university and school partners, while also addressing the requirements of my academic research.

As a researcher, I sought to understand the world through engaging in its transformation, but changing it involves real people, working in real systems, facing real constraints. It is a core priority of the Change Laboratory methodology that we work with real subjects pursuing their real objects. That is the basis of our scholarly knowledge production.

A further challenge related to the timing and duration of sessions. Because the Change Laboratory was conducted during the academic year, each participant (schoolteachers, lecturers and students) had their own scheduling constraints. When the school was selected as part of the intervention unit, Friday afternoons at 1.15pm, immediately after the final school class of the week, were identified as the most viable time for schoolteachers. This did exclude some of the university lecturers and students who had initially expressed interest in this project as they were unavailable at that time. This was a pragmatic constraint that shaped the composition of the intervention group.

Another significant challenge arose during the participant recruitment process. Only one female computing student from the university volunteered to participate. Ideally, I would have liked to include a broader group of female first and second year students, as they would have brought fresh insights from their recent experiences of secondary level computing and their transition into higher education. However, the low level of uptake was not hugely surprising, given the small number of female students enrolled in those cohorts to begin with, a fact which further highlights the very issue this research is attempting to address, the persistent underrepresentation of females in computing programmes.

These limitations, while constraining in some aspects, are also part of the reality of working in real-world educational systems. They point to both the necessity and the challenge of doing collaborative, contextualised work with stakeholders who are already embedded in complex institutional arrangements.

I revisit and reflect further on these limitations and their implications in Chapter 7.

4.11 Summary

This chapter has set out my research design as well as outlining how I selected the intervention unit and the recruitment process of participants. Next, in Chapter 5, the Findings chapter, I will first describe the final design of the outreach initiative followed by a presentation of the data gathered during the CL sessions that led to the final design. This data is then analysed in Chapter 6 to answer my research questions.

Chapter 5 Findings

5.1 Introduction

This chapter presents the findings of this research-intervention. It is divided into two parts.

In *Part One: The Design of the Proposed Joint Activity System* (section 5.2), as the name suggests I begin by presenting the design of the proposed outreach initiative as co-designed by participants during this Change Laboratory research intervention. It will then provide a description of the proposed design of the joint activity system, the aim of which is to first provide an understanding of the system and why it was felt to be important by participants.

In *Part Two: How the Design Emerged and Participants Perceptions of the Design* I step back from the design presented in Part One, and trace through why the proposed design of the joint activity system looks the way it is by showing the design steps and process that led up to the proposed joint activity system, how the design was realised by participants in the process. I also reveal what participants thought about the design following this Change Laboratory research intervention.

It will be evident in this part, that various contradictions were overcome during the process in addition to various contradictions that still exist or have newly emerged within the process.

5.2 Part One: The Design of the Proposed Joint Activity System

I begin this section by first looking at the eventual activity system designed, in order for us to better appreciate how the design process led to its gradual emergence. I will provide a description of the proposed joint activity system and its overarching logic and discuss each of the elements of the activity system in terms of how they address the priorities of the overall activity system. The aim of this is to first provide an understanding of the system and why it was felt to be important to participants before looking at the process that led to its design.

As discussed in previous chapters, my aim with this research-intervention was to give the participants in different roles differentiated by speciality and authority the opportunity to design the process and during this process I would observe and analyse them working together. I also wanted to actively engage and facilitate the co-design of an outreach initiative and promote change. To do this, participants from both partners were confronted with complex challenges of their work practice. During the Change Laboratory workshops, they were provided with the resources and space to identify and analyse these complexities, allowing for the formulation of outreach designs that were then considered and modelled. This led to the design of an evolved activity system that encapsulates the revised practices participants feel are needed to overcome the challenges identified. A number of new and revised practices have emerged, the majority of which are at a concrete applicable level, while others remain more abstract, given the scope of this Change Laboratory which focuses on the questioning, analysis, modelling, examination, and reflection stages of the expansive learning cycle (as discussed in the Abstract and Introduction Chapters). Many activities of the design presented will take time to solidify into concrete practice, however, it is possible to present an emerging model of the future interacting activity system as illustrated in Figure 5.1.

Figure 5.1 presents the design of the outreach initiative, as designed by participants during this research-intervention. This model depicts the proposed activities between each partner in the university-school partnership that was formed as part of this project. It comprises two activity systems, where the subjects from the two different systems are acting on a partially shared object at the same time while also acting on their own objects. The two activity systems have been designed to fit together, with each supporting the other. Highlighted in the grey boxes are four concepts that were developed by participants during the design process. These are, *the varied and true nature of computer science*, *inclusive computing curriculum*, *diverse cohort of students* and *sustainable collaboration* which applies to both activity systems. Some of these concepts can be found as part of the partially shared object as discussed in Section 5.2.4 and others are part of the mediating artefacts of both activity systems. The formation of these during the workshops is presented in part two of this chapter.

5.2.1 Diagram of Joint Activity System of Outreach Design

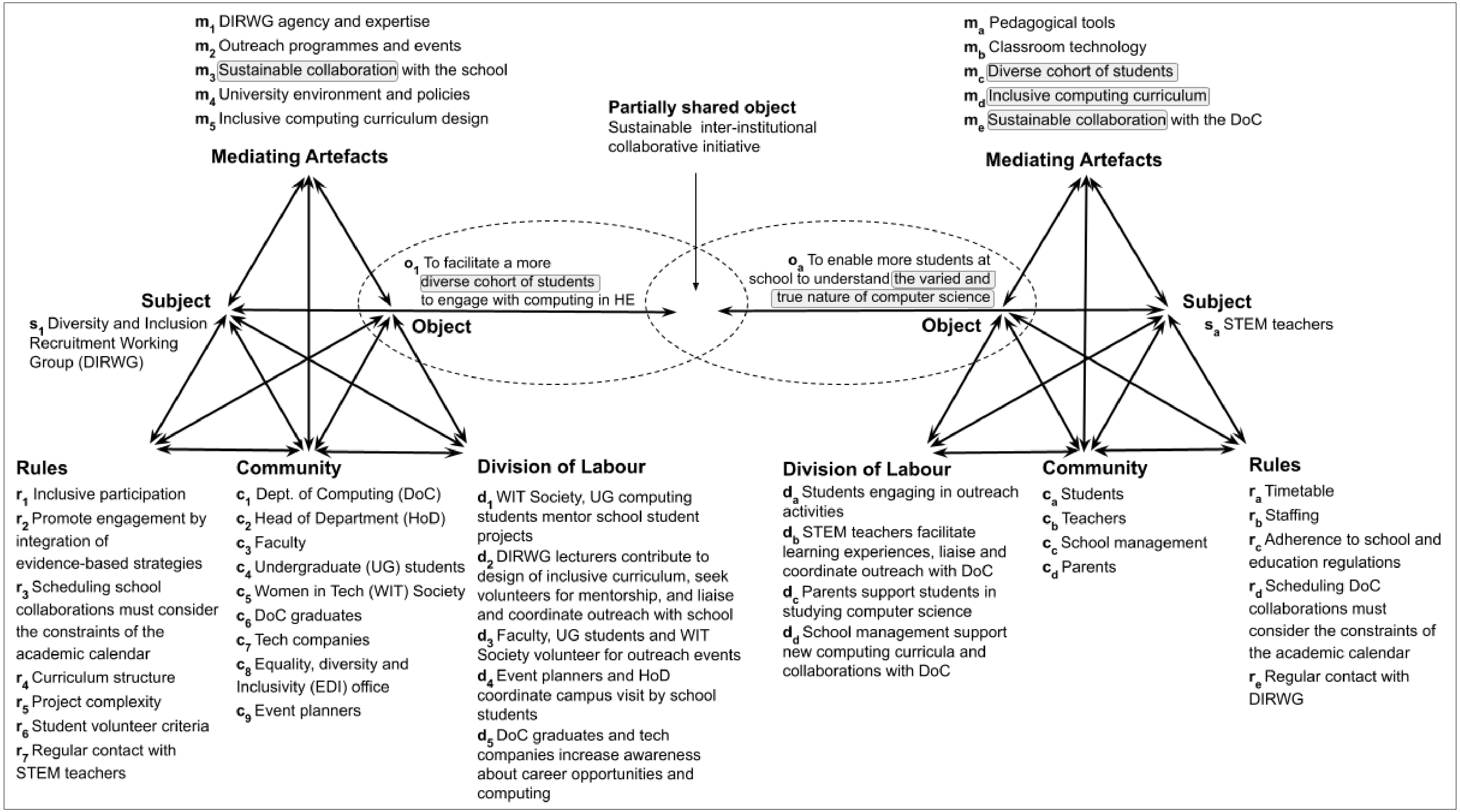


Figure 5.1: Joint activity system of the outreach initiative proposed by University-School participants

It is useful at this point to examine the elements that constitute the joint activity system illustrated in Figure 5.1. In the following sections I will explore the object of each activity system involved in this project, as illustrated in Figures 5.1, and which are in direct relation to the contradictions identified in the early analysis of the activity systems as discussed later in section 5.3. I will then discuss the similarities and tensions in the partially shared object that both institutions are collectively working towards.

5.2.2 The Object of the School's Computer Science Education Activity System

The object of the school's computer science education activity system is to enable more students at school to understand the true and varied nature of computer science. This is labelled in Figure 5.1 as o_a[7].

The material component of the object that the STEM teachers are working on in this activity system is student year groups. The participants conceptualised it this way, focusing on year groups rather than individual students, as it allows them to identify and address collective trends in student misconceptions and engagement, rather than tailoring interventions to individual learning paths. The STEM teachers believe that computer science is often misunderstood as a discipline, with many students having a limited view of its potential applications and career opportunities. Therefore, the STEM teachers motive here is to develop a different kind of student understanding of computer science. To address this, the subjects wanted to present a comprehensive view of computing, emphasising creativity and various sub-disciplines rather than just its exciting aspects. The schoolteachers have noticed that many students struggle with computer science in school due to a lack of understanding, leading to a low number of students choosing the computer science subject in senior years. The teachers find that students often realise that computer science is not what they expected and end up not enjoying it.

To assist students in making a more informed decision, the school's main ICT teacher described the aim of their activity system as follows:

---

[7] I will use this labelling scheme throughout this chapter: the first letter of the element followed by alphabetical numbering (e.g., o_a and r_b) to refer to a specific element of the school's computer science education activity system, and the first letter followed by a whole number (e.g., m_1 and r_2) to refer to a specific element of the computing department's bespoke outreach activity system.

"We need to inform students of what computer science is before they take the Leaving Certificate Computer Science subject, because they haven't a clue right now. So, giving them a view of all the wonderful things that can happen in computer science - that's our main aim." - Schoolteacher 1, W5[8]

All participants agreed with Schoolteacher 1's comment, and university participants, in particular, emphasised the importance of providing students a true sense of what computer science is all about i.e., not just showing students the 'cool' stuff, but rather exposure to a variety of sub-disciplines within computer science. This was demonstrated by one lecturer who stated:

"*we need to be true to students about what computer science really is. And not give them any false information about it. And following that, that they know what they're getting into if they come to study it at a third level*." – Lecturer 6, W5

Ultimately, the desired outcome of this activity is to increase student understanding, interest and confidence to choose computer science in senior cycle years.

5.2.3 The Object of the Computing Department's Bespoke Outreach Activity System

The main object of the Computing Department's bespoke outreach activity system is to facilitate a more diverse cohort of students to engage with computing in higher education (HE). This is labelled in Figure 5.1 as o_1.

The material component of the object that the DIRWG are working on in the Computing Department's bespoke outreach activity system is diverse student recruitment. The group is well aware of the significant gender imbalance in computing programmes worldwide, especially within the university's Computing department, where approximately 15% are females and 85% are males. The Head of Department commented:

"… our [current enrolment] numbers are satisfactory, I think one of the key things we'd like to do is try and get the [gender] balance better, which is one of the key things we're talking

[8] As outlined in Section 4.5.2 of the Research Design chapter, pseudonyms are used for participants when quoting them. I also use a denotation referring to the specific participant and workshop. In this instance, "Schoolteacher 1, W5" indicates a statement made by Schoolteacher 1 in Workshop 5.

about here… So… the primary goal really is to try and get more females really involved."

- Head of Department, W3

The subjects of this activity system, firstly would like to promote computer science among secondary school students, encouraging them to consider pursuing it in college, regardless of the university they choose. Secondly, since the partner school is close to the university campus (<17km), the subjects believe that generating more interest in computer science among students in that school could have a positive ripple effect on diverse student recruitment for the department of computing's programmes.

The DIRWG unanimously agree on the desired product within this activity system. They aim to create an outreach initiative that is not gender-specific and will boost overall interest in computer science in higher education. One lecturer stated:

> "W*e want to be inclusive... whatever outreach we design, it should be inclusive to all. We want to have activities that attract both boys and girls*" – Lecturer 6, W1

The desired outcome of this activity system is achieving a more gender-balanced representation of students pursuing computing in higher education, including the university's own Computing department.

5.2.4 The Partially Shared Object

The bringing together of two activities to design a single initiative creates a *partially* s*hared object* that both activity systems are working towards, while also pursuing their individual objectives. The object is considered partially shared because its interpretation and significance may vary depending on the context and perspectives of the activity systems involved.

From the beginning of this intervention, it was evident that different agendas were influencing the development of the outreach initiative. The participants recognised that despite representing two different institutions each with their own distinct objectives or motives, these two activity systems also share an object, a mutual aim of seeking a new or improved approach to enhance their current activities.

The partially shared object of this project as written by participants, is:

"To create a sustainable collaboration between SETU (Carlow Campus) and Tullow Community School to enable students to understand the varied and true nature of computer science through an inclusive curriculum. This should facilitate a more diverse cohort of students to engage with computing in 2nd and 3rd level education."

The partially shared object embodies the main objective of the initiative: forming a new partnership between both institutes to enhance and sustain collaboration efforts. Participants believe that this shared object will address their concerns, as discussed in the previous two sections.

The initiative aims to present a more accurate portrayal of computing, going beyond just the exciting aspects. By doing so, they hope to prevent students from choosing computer science in senior cycle or entering college with unrealistic expectations, which could lead to losing interest or dropping out.

The material component of the partially shared object that both activity systems are working on is student uptake in computer science. As mentioned earlier, they want to promote computer science education and increase students' interest in the subject.

The subjects expressed the idea that introducing something to a larger number of people should result in a more diverse representation. By increasing exposure to computer science , they aim to attract both girls and boys, aligning with the school's objective of providing a true understanding of computing to all students. This, in turn, satisfies the DIRWG's goal of reaching a broader audience (especially females), increasing their interest and understanding of studying computer science in HE.

The desired outcome is a sustainable outreach programme that caters to the needs of both institutions. They aim to expose students to an inclusive computing curriculum, showcasing its true nature, and fostering interest in computing at both secondary school and university levels. The goal is to establish a programme that can run for many years into the future. As one lecturer stated:

"*we want to be able to, let's say, design this initiative, and then you do that once and then it's able to be repeated with different groups in the same year. And then multiple years after that*." – Lecturer 5, W5

It was also highlighted that to do this, the outreach must be relatively easy for both institute's to coordinate and run.

This proposed bringing together of two activities, results in an object that is partially shared but partially in tension also. Both activity systems aim to promote computer science education and increase students' interest in the subject, however they differ in their objectives, focusing on distinct stages of a student's education and different aspects of computer science.

The object of the school's computer science education activity system is to enable more students at school to understand the varied and true nature of computer science. Their objective is to help students make informed decisions when considering the optional computer science subject in senior cycle years. Their focus is on informing and educating 2nd level students about the field, with the intention of cultivating a deeper understanding of the discipline and fostering further engagement with it.

The object of the computing department's bespoke outreach activity system is to facilitate a more diverse cohort of students to engage with computing in higher education. They aim to achieve a more balanced student population enrolling in their department's computing programmes, emphasising outreach and inclusivity to attract students of all profiles into tertiary level computing.

Overall, the proposed bringing together of these two activity systems aims to capitalise on the strengths and resources of both the university's Computing department and the secondary school. The goal is to offer a more engaging and inclusive computing curriculum for school students and establish a pipeline of diverse and motivated students who will pursue computer science in higher education.

5.2.5 The School's Computer Science Education Activity System

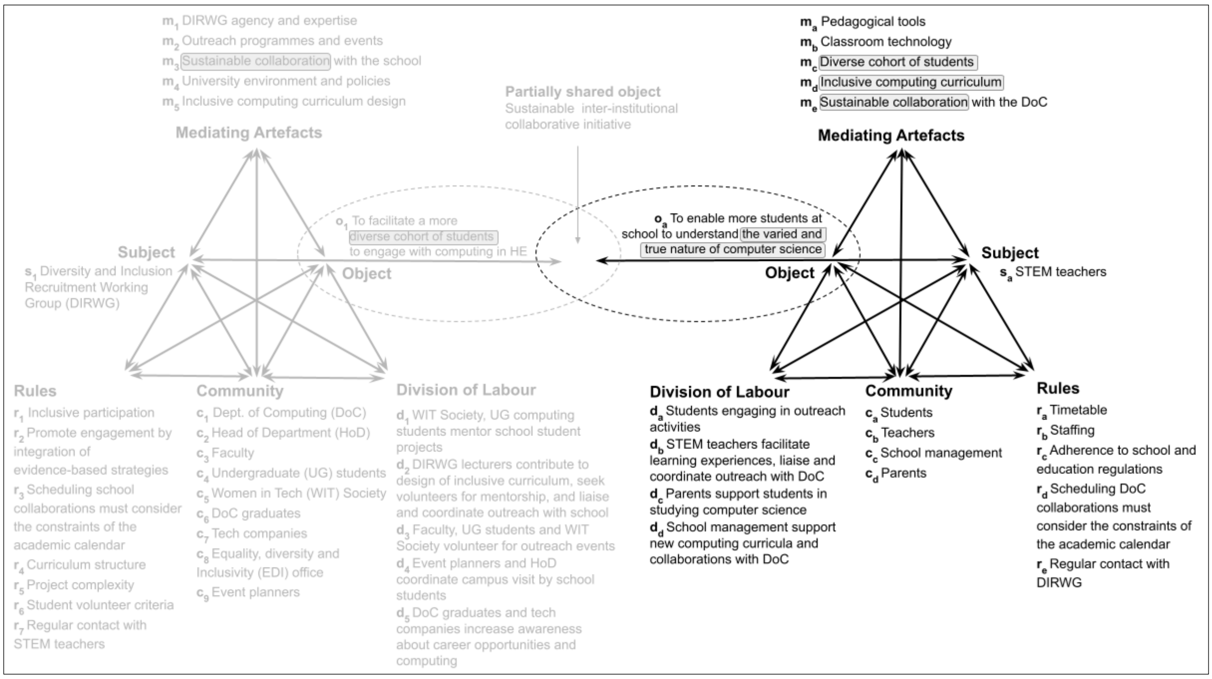


Figure 5.2: The Proposed School's Computer Science Education Activity System

The activity system model on the right, highlighted in Figure 5.2, represents the secondary school's computer science education activity. The object of this system was previously discussed in Section 5.2.2 and will not be presented here.

5.2.5.1 Subject

The subjects engaged in the school's computer science education activity system (s_a) are a group of experienced STEM teachers responsible for promoting and delivering various subjects to secondary school students such as ICT, Maths, Science, Engineering and Art. They also help to support the unique learning needs of students, such as those with autism and other special educational requirements. This selected group of STEM teachers will serve as the primary coordinators of the school's computer science activities as prescribed in the outreach programme designed by participants. They will liaise with the DIRWG to ensure the success and sustainability of the initiative. As the newly designed computing curriculum is integrated into the school's curriculum, additional STEM teachers may be included in this subset, based on the specific subject allocations and timetables for each academic year.

These STEM teachers are the people who co-designed this outreach initiative with the subjects from the Computing Department's bespoke outreach activity system and are driven to advance the computer science educational opportunities available to their students. As described in Section 4.5.2, the schools main ICT teacher recruited four other teachers to participate in this research-intervention. Three STEM teachers in the school deliver computing, each in different capacities. However, only one teacher focuses primarily on computing as their main subject area, while the remaining teachers primarily handle other subjects such as maths or engineering.

While all STEM teachers expressed various experiences and motivations around creating change in computer science education in the school, it was the main ICT teacher in particular who had experienced cases where computer science was not a popular subject choice amongst students. Resulting in low numbers opting to study it at senior cycle. Additionally, the ICT teacher found that those who did choose it were finding the subject is not what they thought it would be.

5.2.5.2 Mediating Artefacts

The mediating artefacts available to the STEM teachers to achieve the object of their activity system can be divided into five categories; pedagogical tools, classroom technology, diverse cohort of students, inclusive computing curriculum and sustainable collaboration. These are denoted in Figure 5.1 as m_a, m_b, m_c, m_d, and m_e, respectively.

Pedagogical tools (m_a). Participants perceived this category of mediating artefact as essential for effective mediation in teaching computer science. The workshops highlighted that the proposed design needed to integrate these pedagogical tools, which encompass teaching techniques, approaches and teacher agency. These tools are pivotal for enabling students to understand the varied and true nature of computer science. By mediating learning through hands-on activities, project-based learning, and other interactive methods, these artefacts empower STEM teachers to engage students across diverse learning styles and backgrounds. This mediation ensures that the learning environment is engaging and reflective of the broad spectrum of computer science fields. By employing these pedagogical tools, STEM teachers can foster an environment where the object (o_a) of understanding the varied and true nature of computer science is effectively achieved, contributing to a more accurate and enticing portrayal of the field.

Classroom technology (m_b). Participants perceived this category of mediating artefact as crucial for the mediation of computer science education. The workshops underscored the necessity of designing the educational environment to include classroom technologies such as software and physical computing devices like computers, tablet trolleys, Micro:bits and projectors available in the school. Participants believe these artefacts enable STEM teacher to offer dynamic and interactive learning experiences, mediating the object (o_a) of understanding the varied and true nature of computer science. The subjects noted that the range of computing software and hardware available, equips STEM teachers to facilitate engaging lessons that capture students' attention, accommodate diverse learning styles, and demonstrate the practical applications of computer science. By leveraging classroom technology, STEM teachers can effectively communicate the varied and true nature of the field, fostering a more comprehensive understanding and genuine enthusiasm for computer science among students.

Diverse cohort of students (m_c). Participants perceived this category of mediating artefact, a concept conceived during the design process, as essential for the mediation of computer science education. The workshops emphasised that the diverse cohort of students directly supports STEM teachers by enriching the learning environment with a variety of perspectives and experiences. Interacting with a diverse cohort in a mixed gender secondary school, creates a dynamic classroom atmosphere that mirrors the real-world context of computer science. STEM teachers can leverage this diversity to facilitate discussions, share varying viewpoints, and introduce a range of applications within the field, mediating the object (o_a) of understanding the varied and true nature of computer science. This artefact empowers STEM teachers to tap into the collective knowledge and experiences of students, providing valuable context and authenticity to lessons, ultimately enabling more students across the three junior cycle years to grasp the varied and true nature of computer science.

Inclusive computing curriculum (m_d). Participants perceived this category of mediating artefact, also a concept developed during the design process, as vital for the mediation of computer science education. The workshops emphasised the importance of designing inclusive computing curriculum to support the overarching goal of the schools activity system, to enable more students to understand the varied and true nature of computer science. This curriculum directly supports STEM teachers by providing a framework that integrates a broad spectrum of topics, perspectives, and applications with computer science. Designed and documented by the DIRWG lecturers for STEM teachers as part of this research-intervention, it includes detailed notes, well-structured lesson plans, engaging activities and other valuable teaching aids. By incorporating inclusive content, diverse examples and relevant projects, this curriculum mediates the object (o_a)

of understanding the varied and true nature of computer science. It equips teachers to challenge stereotypes, cater to diverse learning styles, and foster a deeper appreciation for the field among students throughout their junior years. This artefact also enables students to explore the discipline beyond traditional computing offerings in school.

Sustainable collaboration (m_e). Participants perceived this category of mediating artefact, a concept conceived during the design process, as critical for the mediation of computer science education. The workshops highlighted the necessity of fostering an enduring partnership between STEM teachers and the DIRWG in the university's Department of Computing. This sustainable collaboration supports the object (o_a) of enabling more students to understand the varied and true nature of computer science by providing a multifaceted perspective on the field. This artefact empowers STEM teachers by granting access to a broader network of expertise, resources, and real-world insights through an open communication channel established with the DIRWG. This collaborative engagement enables the teachers to infuse their lessons with the inclusive computing curriculum, mentorship programme between undergraduate computing students and school students and outreach events and activities with the university's Department of Computing. By doing so, STEM teachers can offer enriched educational experiences, allowing more students to perceive the varied and true nature of computer science.

5.2.5.3 Rules

The rules and regulations that govern the activities of the STEM teachers in this activity system include the timetable, staffing, adherence to school and education regulations, logistics and time constraints around aligning joint events with the Department of Computing with the academic calendar, and the need for the school to regularly talk to the DIRWG.

Timetable (r_a). Participants emphasised that the design requires the new curricula proposed to be integrated into the school timetable to increase student exposure to computing. This would require school management's support to add two new computing subjects for second and third year students.

Staffing (r_b). Participants highlighted that the introduction of new curricula depends heavily on the school's resources. The two new computing subjects will require adequate classroom or computer lab space for all second and third year students, while adhering to the school's class capacity policies. Additionally, a sufficient number of STEM teachers qualified to teach computer science will be necessary.

Adherence to school and education regulations (r_c). Participants emphasised that the computing curriculum and its delivery must comply with standards and policies set by the Department of Education, a department of the Irish State with responsibility for education and training. Consideration would also need to be given to curriculum standards set by other national education bodies such as the NCCA (National Council for Curriculum and Assessment). Participants also highlighted that teachers must also adhere to school policies on student assessment, classroom management and professional development.

Scheduling DoC collaborations must consider the constraints of the academic calendar (r_d). Participants highlighted that certain aspects of the design, such as the timing of school visits to the university campus, need to be scheduled for specific times in the academic year.

> "*thinking about it, they [students] choose their subjects for fifth year in February. So by coming over to campus after that, it might defeat the purpose a little bit. Whereas if it's [the site visit] fresh, and it's exciting, and they've seen the college, then they may want to choose Computer Science for fifth year*" – Schoolteacher 1, W4

Regular contact with DIRWG (r_e). Participants emphasised the need for STEM teachers to regularly communicate with the DIRWG to ensure proper delivery of the initiative and seek support if needed. Teachers should collaborate with the DIRWG to develop and implement strategies for promote computing education, schedule site visits, and organise outreach activities. Additionally, teachers should monitor student engagement and provide feedback to the DIRWG for continuous improvement and sustainability.

5.2.5.4 Community

The school's computer science education activity system will need to develop a community, consisting locally of school students, teachers in the school, school management and parents. This community was proposed by the STEM teachers during the intervention when they were considering who should be involved in the participation, management, organisation and teaching of computing. They also considered other people that would need to be involved when students are considering subject choices for senior cycle. The people identified were students ($c_{a,}$), teachers

(c_b) to deliver computing subjects and career guidance teachers who may need to communicate with the students and their parents *(c_d)* (e.g. at parent-teacher meetings) to promote the benefits of computer science education and encourage students to choose the computer science subject in senior cycle. The STEM teachers also talked about the potential need to collaborate with other teachers *(c_b)* in the school to integrate computer science education into different subject areas such as science, maths and engineering. School management *(c_c)* were also identified as needing to support computing curriculum and outreach within the school.

5.2.5.5 Division of Labour

When looking at the various members of the community and how they will need to work together to achieve the object of the activity, the division of labour in the school's computer science education activity system therefore needs to involve differentiated roles for the students, teachers, school management and parents.

It is necessary to have STEM teachers to facilitate learning experiences *(d_b)*. These teachers will be responsible for teaching the curriculum to enable more students at the school to understand the varied and true nature of the discipline.

> "*I just think quickly that the one thing on our end that we just want to be mindful of is… let's say the first year 8 week block, if we had that in a way that we could basically put any teacher in as long as the basic knowledge is there… that'd allow us to say to management, look we might need more experienced teachers in the area to deal with the third year eight week block, because it's going to be more complex*" – Schoolteacher 4, W4

The STEM teachers will need to liaise and coordinate outreach activities, such as site visits, mentorship programme and third year projects, with the DoC.

The students are responsible for engaging in outreach activities *(d_a)* and applying the knowledge attained from studying the curriculum. The parents *(d_c)* of these students are responsible for supporting their children when studying computer science and to encourage them to choose the optional senior cycle computer science subject.

> *"… hopefully students will be going home to their parents and saying their enjoying the computing subjects and that they'll encourage them to choose computing for the leaving cert or… to go on to study it at a third level*." – Lecturer 6, W6

School management *(d_d)* who have the authority to do so, will be responsible for supporting new computing curricula and collaborations with DoC, this includes providing resources for the STEM teachers to promote and deliver computer science education in the school and for students to learn and apply their new computing skills and knowledge. Support would also be needed from school management for the practicalities around site visits and other proposed outreach activities with the university. With the addition of two new computing curriculum, other teachers who have the relevant knowledge or qualification in computer science would be needed for delivery. School management would be responsible for the hiring or allocation of staff.

> *"…if I give another teacher that third year project they'll all be completely lost. Speaking to the vice principal, she's one that does the timetable, I've made her aware of it [the need for additional resources]. So she would probably require more… well I'm definitely there, and maybe [schoolteacher 4] might be included, and [schoolteacher 2], who are all part of this."* - Schoolteacher 1, W5

5.2.6 The Computing Department's Bespoke Outreach Activity System

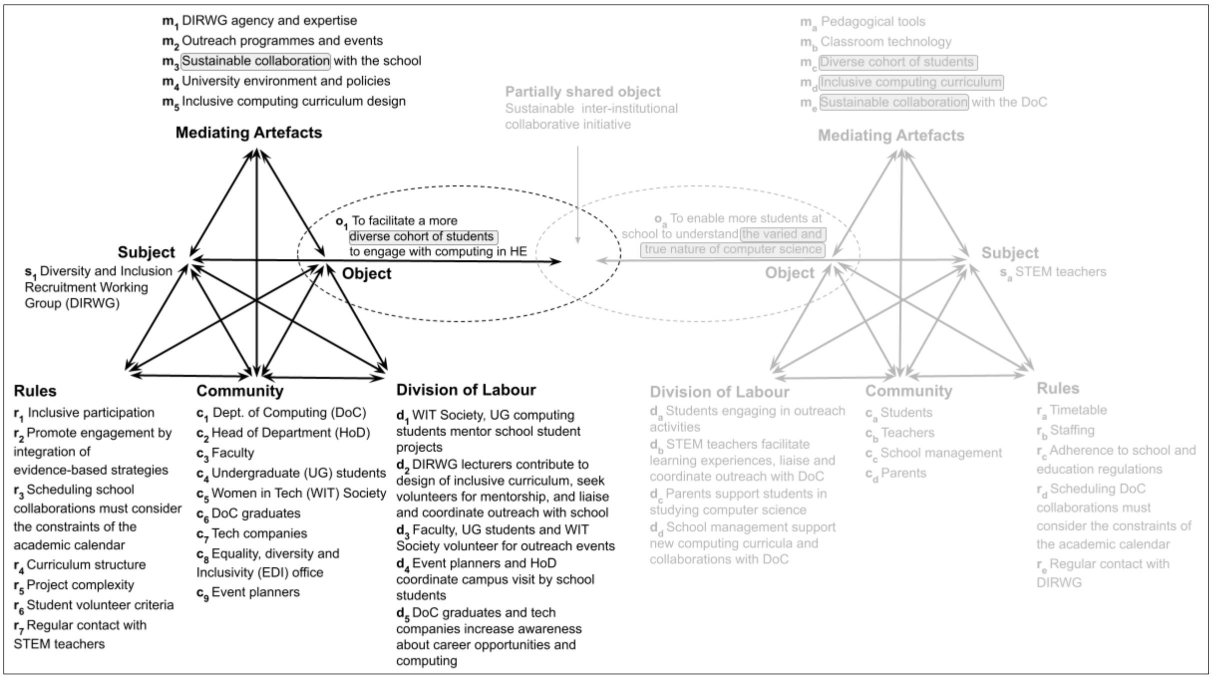


Figure 5.3: The Proposed Computing Department's Bespoke Outreach Activity System

The activity system model on the left, highlighted in Figure 5.3, represents the Computing department's bespoke outreach activity. The object of this system was previously discussed in Section 5.2.2 and will not be presented here.

5.2.6.1 Subject

The subject of the Computing Department's bespoke outreach activity system (s_1) is a diversity and inclusion recruitment working group within the university's Computing department, which I formed for this research-intervention and whom I will refer to as the DIRWG. This group is composed of individuals from the Computing department, the Head of Department, faculty and undergraduate students who specialise in different areas of computer science. This working group have a keen interest and passion in promoting diversity and inclusion in higher education (HE) computer science education and really want to push this initiative forward to improve the gender balance of enrolments on the departments computing programmes also.

This subset of people within the department and university, co-designed the outreach initiative with the subjects from the school's computer science education activity system, all of whom made decisions based on their subjective experiences and opinions. Although faculty members specialise in different sub-disciplines of Computer Science, and some have prior involvement in diversity and inclusion interventions, their effectiveness in driving meaningful change must be evaluated. For example, members of the DIRWG were involved in the Department of Computing's recent application process for the Athena Swan bronze award. The Athena Swan Charter is a framework which is used across the globe to support and transform gender equality within higher education (HE) and research (Advance HE, n.d.). The person who took the lead on the department's application, in addition to other people involved in the application, were members of the DIRWG in this research-intervention. Additionally, two faculty participants were also heavily involved in the EUGAIN COST ACTION CA19122 which is a European network for gender balance in informatics (EUGAIN, n.d.). The undergraduate students involved were first year and second year students studying different sub-disciplines of computing and while they may have limited experience in outreach, their demographic and recent school experiences are considered valuable to the co-design process.

Members of this group will bear the prime responsibility for collaborating with the school and coordinating the departments activities as co-designed and prescribed in the proposed outreach design during this research-intervention.

5.2.6.2 Mediating Artefacts

The actions of the DIRWG working on facilitating a more diverse cohort of students to engage with computing in HE is mediated by five categories of mediating artefacts, DIRWG agency and expertise, outreach programmes and events, sustainable collaboration with the school, university environment and policies, and inclusive computing curriculum design.

DIRWG agency and expertise (m_1). The participants perceived this category, the DIRWG agency and expertise, as a crucial mediating artefact in their efforts to cultivate a more diverse cohort of students engaging with computing in higher education (o_1). Emphasising the necessity of incorporating this mediating artefact, the workshops highlighted that the proposed design must facilitate the mediation between the DIRWG's actions and the overarching objective. This mediation is vital in ensuring the effective allocation of resources and decision-making processes. The DIRWG's expertise, derived from specialised knowledge, mediates the development of strategic and informed outreach initiatives aimed at attracting underrepresented students including females. By integrating this artefact, the DIRWG's agency is empowered, allowing them to translate their intentions into impactful actions. This ensures that their efforts are not only strategic and informed but also aligned with the goal of facilitating a more diverse cohort of students engaging with computing in higher education.

Outreach programmes and events (m_2). Participants perceived outreach programmes and events as essential mediating artefacts for cultivating a more diverse cohort of students engaging with computing in higher education (o_1). Emphasising the need to incorporate this mediating artefact, the workshops stressed that the proposed design must facilitate the mediation between outreach activities and the overarching objective. These activities, including school and university campus site visits, mentoring programmes and support programmes, act as conduits for the DIRWG to reach and engage with a broader demographic of potential students. Through organising site visits and mentoring programmes tailored to all student profiles, the DIRWG mediates a 'real' connection between the university and school, making it more personal and conducive to effective and ongoing collaboration. This mediation allows the DIRWG to directly interact with prospective students, dispel stereotypes, and showcase the inclusive nature of the computing field. By integrating this artefact, the DIRWG can convey the benefits of computing education and alleviate barriers to entry, ultimately contributing to the realisation of a more diverse and inclusive computing higher education landscape.

Sustainable collaboration with the school (m_3). The participants perceived the sustainable collaboration, with the school as a vital mediating artefact for fostering a more diverse cohort of students engaging with computing in higher education (o_1). Emphasising the importance of this mediating artefact, a concept formed during the design process, the workshops underscored the need for the proposed design to facilitate mediation between the DIRWG and the overarching objective. By nurturing an enduring partnership with the secondary school the DIRWG can amplify their efforts through shared resources such as Raspberry Pi devices for third-year student projects, and diverse perspectives. This collaboration mediates the development of innovative strategies for attracting underrepresented students. By integrating this artefact, the DIRWG is empowered to tap into collective strength, enabling them to devise a sustainable initiative that transcends the university's boundaries. Through fostering ongoing collaboration, the DIRWG can create a lasting impact, actively contributing to the realisation of a more diverse student cohort engaging in computer science at higher education (o_1).

University environment and policies (m_4). The participants perceived the university environment and policies as crucial mediating artefacts for facilitating a more diverse cohort of students engaging in computing in higher education (o_1). Emphasising the necessity of this mediating artefact, the workshops highlighted that the proposed design must facilitate the mediation between the DIRWG's activities and the overarching objective. The university environment, characterised by a campus-wide culture that champions equality, diversity and inclusion (EDI), provides a supportive context for the DIRWG. The university's commitment to achieving equity of opportunity for all is demonstrated through its established EDI office and policies, its attainment of Athena Swan awards at both university and department levels, its Gender Equality Action Plan and the Women in Technology society. By integrating this artefact, the DIRWG is empowered to enact tangible change, aligning their activities with the goal of facilitating a diverse cohort of students in computing in higher education (o_1). This mediation within the structural and policy framework of the university creates an inclusive, welcoming, and supportive atmosphere, ultimately encouraging greater diversity and engagement in higher education computing programmes.

Inclusive computing curriculum design (m_5). Participants perceived the inclusive computing curriculum design as a pivotal mediating artefact for facilitating a more diverse cohort of students engaging in computing in higher education (o_1). Emphasising the importance of this mediating artefact, the workshops stressed that the proposed design must facilitate the mediation between the subjects and the overarching objective. By designing a curriculum for STEM teachers that is diverse, culturally sensitive, and accessible, the DIRWG can directly influence the learning experience of all students, especially those from underrepresented groups. Crafting curricula that highlight diverse perspectives, address real-world challenges, and incorporate inclusive pedagogies empowers students' connection with computing in meaningful ways. This artefact not only encourages engagement but also helps counter barriers that historically deterred certain groups from pursuing computing. By integrating this artefact, the DIRWG aids in attracting and retaining a diverse student body, providing a relevant and inclusive educational experience that aligns with the object of facilitating a more diverse cohort of students in computer science in higher education.

5.2.6.3 Rules

The DIRWG were invited to discuss the rules and norms that they would have to adhere to as part of their role in the activity system and they identified the following rules, inclusive participation, promote engagement by integration of evidence-based strategies, scheduling school collaborations must consider the constraints of the academic calendar, curriculum structure, project complexity, student volunteer criteria, and regular contact with the STEM teachers.

Inclusive participation (r_1). Participants agreed that the initiative is designed to include and cater to the diverse interests and needs of all students, promoting an environment of inclusive participation.

Promote engagement by integration of evidence-based strategies (r_2). Participants identified the need to foster an environment that encourages interest, interaction, questions, and discussions from all students and the importance of creating a safe space where students can freely engage and express their thoughts. To do this, evidence-based strategies found in the literature to support and attract minority groups, in particular females, will be employed such as two-subject title programmes and opportunities for hands-on and creative activities.

Scheduling school collaborations must consider the constraints of the academic calendar (r_3). The DIRWG identified the need for the campus visit and the school visit to be scheduled at particular times of the academic calendar outside of university assessment periods which are times when faculty and undergraduate students are most likely to be unavailable to volunteer for outreach activities and events.

Curriculum structure (r_4). Participants emphasised that the computing curricula must be delivered in the order with which it has been designed with specific topics organised across the three years of the junior cycle to create a progressive learning experience for students.

Project complexity (r_5). The participants highlighted the need for projects set for students in third year to be of a specific topic agreed by participants, who considered students' interests. They identified the need to tailor project complexity to the students' age groups and levels of expertise, ensuring that projects are appropriate, feasible and of interest.

Student volunteer criteria (r_6). The DIRWG identified second year undergraduate students as the ideal students to recruit for outreach activities and events with the school, as first year students would still be settling into university and courses, third year students would be off campus on work placements and fourth year students would be working on final year projects.

> "*I guess this is something we can't fully decide right now, it will come down to volunteers from our undergrad students. Ideally, second years would be the best students go out [to the school] because first years are still quite new to it. It really depends on the time of year that the visit would happen. Third years will be gone on work placement and fourth years will be too busy with final projects. So if we can get some second years to volunteer, our HoD has agreed to support a bus going out [to the school] to visit the fifth years*"
>
> – Lecturer 6, W5

Regular contact with STEM teachers (r_7). Participants emphasised that regular communication and collaboration must occur between the DIRWG and the STEM teachers to ensure the smooth running of the initiative. The DIRWG should maintain ongoing discussion with the STEM teachers, offering assistance and support as required. Together, they should develop and implement strategies to promote computing education to all student profiles in the school. They should also plan and organise site visits and other outreach activities collaboratively. They should seek student feedback and monitor participation levels to gauge the effectiveness of the initiative. Additionally, the DIRWG should have the opportunity to update the inclusive computing curriculum regularly, ensuring it remains up-to-date, engaging and sustainable over time.

5.2.6.4 Community

The Computing Department's bespoke outreach activity system, as discussed by the DIRWG, will require the active involvement of a local community, including the department *(c_1)* itself, the head of department *(c_2)*, faculty *(c_3)*, undergraduate students *(c_4)*, the Women In Technology society *(c_5)*, DOC graduates *(c_6),* tech companies *(c_7),* EDI office *(c_8),* and event planners *(c_9).* The DIRWG recognises the importance of collaborating with this community to successfully implement the outreach initiative and to foster a more diverse group of students engaging with computing in HE. They highlighted the need for support from faculty and undergraduate students within the department. Event planners will be essential when organising site visits to the university campus by school students. Additionally, the involvement of the EDI office and the Women in Technology society may be necessary, as they share an interest in promoting diversity and inclusion within the initiative. Furthermore, the working group may need to work with relevant tech companies and the computing department's graduates to increase awareness amongst school students about the career opportunities available in computer science. Such collaborations will contribute to the overall success and effectiveness of the outreach initiative.

5.2.6.5 Division of Labour

The DIRWG emphasised the importance of the WIT society and undergraduate computing students mentoring *(d_1)* school students during their projects. They also emphasised the role of the DIRWG lecturers in contributing to the design of an inclusive curriculum for the school, seek volunteers for mentorship, and they should liaise and coordinate outreach with the school *(d_2)*. In support of the initiative, the department of Computing faculty and undergraduate students, along with its Women in Technology society, will volunteer for outreach events *(d_3).* The university's event planners and Head of Department will coordinate campus visit by school students *(d_4)*. There will be a need for DoC graduates and tech companies to increase awareness about career opportunities and computing *(d_5)*.

5.2.7 Contradictions in the Design of the Proposed Joint Activity System

The proposed design in Figure 5.1, is the result of participants posing solutions to contradictions identified in the early analysis of both activity systems, as discussed in the next sections. While various contradictions to the existing activity systems were overcome during the process, others remain and new contradictions also emerged. Figure 5.4 shows a simplified version of the proposed design highlighting five contradictions that remain unresolved at the time of the final workshop in this thesis.

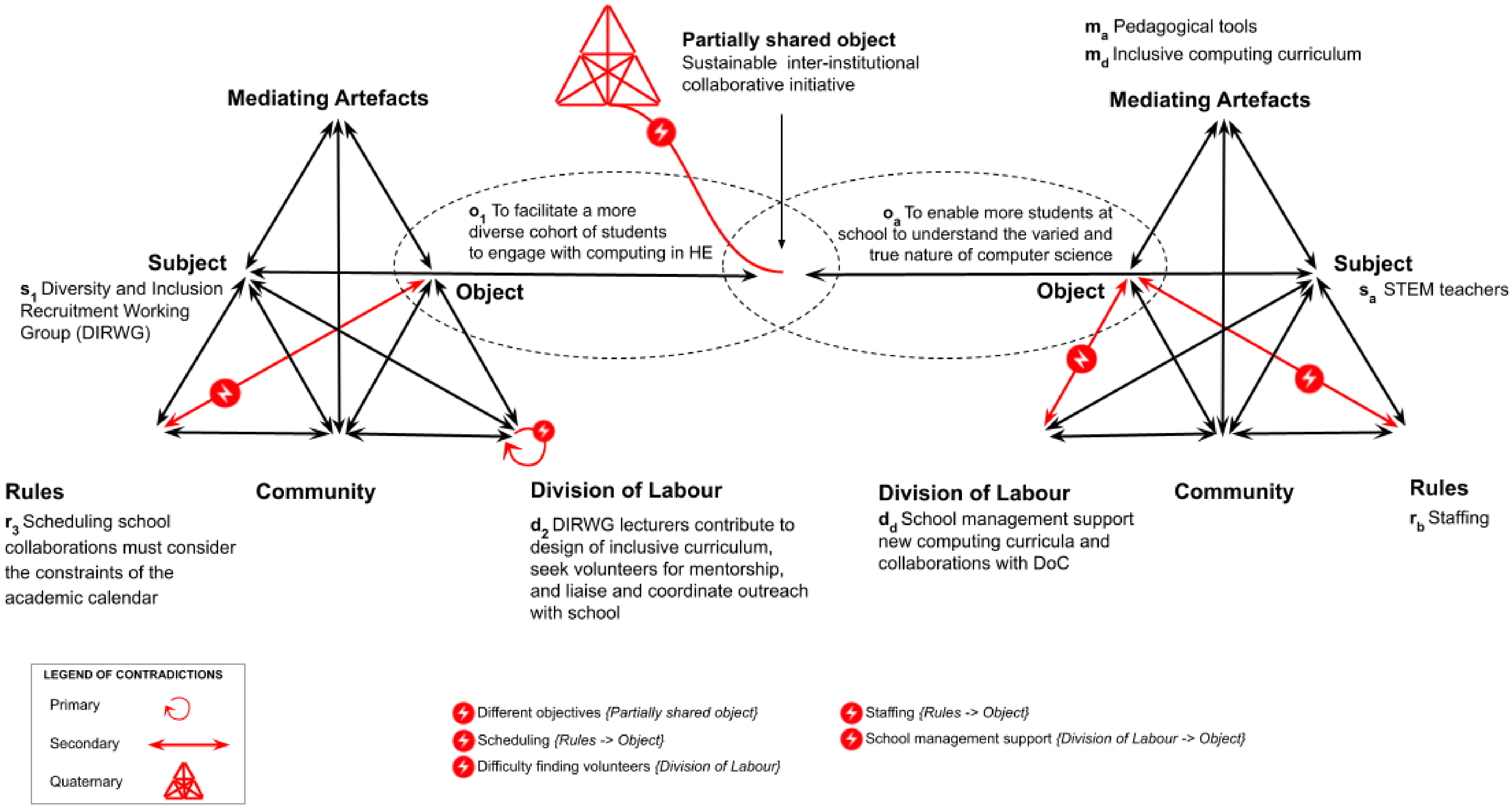


Figure 5.4: Contradictions in the Proposed Design

5.2.7.1 Ongoing issues with the proposed design

The following are issues which were recognised by participants and which they felt might be problems or potential pitfalls of the design of their proposed outreach initiative. By the end of this Change Laboratory, participants did not try to redesign the activity system to avoid them because certain components relied on information that was not yet known and would only be clarified during the planned implementation in the upcoming academic year. These are labelled as contradictions in red in Figure 5.4.

- *Different objectives*. This contradiction is categorised as a quaternary contradiction as it occurs between the two interacting activity systems involved. While each activity system are both in agreement on the same shared goal (partially shared object), it is recognised that each of the two activity systems also have their individual objective as well as rules which may be in conflict (e.g. academic calendars).

- *Difficulty finding volunteers*. This is categorised as a primary contradiction as it occurs within the division of labour element of the Computing department's bespoke outreach activity system. Lecturers in the DIRWG expressed their concern with securing undergraduate students to volunteer for the mentorship programme due to their busy schedules, in addition to lecturers who are needed to plan, coordinate and partake in outreach events.

  > *"… right now you wouldn't have much hope of getting too much help from 2nd, 3rd or 4th year students, because they've got so many deadlines... "* – Head of Department, W3

- *Staffing*. This is categorised as a secondary contradiction as it exists between the rules and object elements of the schools computer science education activity system. Participants highlighted the possibility that the school may need to employ additional STEM teachers to effectively implement the new computing curriculum. This would depend on existing staffing and resources.

- *Scheduling*. This is categorised as a secondary contradiction as it occurs between the rules and object elements of the Computing department's bespoke outreach activity system. Participants emphasised the significance of scheduling the site visit to the university campus for the third year school students by February of the academic year. This timeframe enables students to make informed subject option choices for the senior cycle, especially regarding computer science, prior to the cut-off date. By experiencing interactions with undergraduate computing students and learning about their journey from school to college and seeing examples of computing projects they have worked on, the student can better evaluate whether or not to select computer science as a subject for the senior cycle.

> "*they [students] choose their subjects for fifth year in February. So by coming over to campus after that, it might defeat the purpose a little bit. Whereas if it's [the site visit] fresh, and it's exciting, and they've seen the college, then they may want to choose Computer Science for fifth year*" – Schoolteacher 1, W4

- *School management support*. This is categorised as a secondary contradiction as is occurs between the division of labour and object elements of the schools computer science education activity system. It was noted for this proposed design to work that it is key to obtain approval and support from the school management for this outreach initiative. Without their 'buy-in' to this proposed initiative and the integration of additional computer science curricula to their current practice and any other required resources (i.e. staff) this will not work successfully.

I will next describe how the proposed joint activity system was designed by participants.

5.3 Part Two: How the Design Emerged and Participants' Perceptions of the Design

The aim of this section is to explain how the design was realised by participants, by tracing the design process. I will do this by scrutinising workshop video recordings (9hrs+), transcripts, task stimuli, our shared workspace on Notion and my own reflective research diary notes. My intention is to convey, chronologically, data from each workshop under the following headings:

- **Design**:
  - details my intended plan for the workshop *(example in Section 4.6.2 in Table 4.2)*
- **Progress**:
  - reports how the workshop progressed, supplemented with images of the workshop and artefacts captured
- **Implications**:
  - highlights the core takeaways from the workshop and any contradictions that emerged. This section will be strengthened by a visual representation of the interacting activity systems at that point in the design, the format of which is provided in Figure 5.5.
- **Reflective research diary notes:**
  - personal notes I retained *(described in Section 4.7.3)*

5.3.1 Prior to workshops

I began the design process in the typical way with only a broad concept. I knew I was interested in finding ways to attract more females into computer science, in particular in higher education. Through initial conversations with people including my thesis supervisor and my Head of Department the concept expanded to involve the Change Laboratory methodology and identifying a local secondary school with whom I could work with. As discussed in Section 4.6.1, I visited a secondary school and met with the main ICT teacher to propose this project. I also spoke to several people within the department of Computing, where I am employed. From there, I did some initial work with the school and the department of Computing separately.

Through one-on-one and group discussions with the ICT teacher and faculty members, I learned of various outreach initiatives that the school and the department had previously undertaken in their own settings. These people shared their opinions on the success or failure of such outreach initiatives which I became aware of only in outline. For instance, I learned about the school's unsuccessful attempt to establish a lunchtime computing club due to lack of student attendance. I learned that the Department of Computing run coding classes for school kids annually but the impact this has on first year enrolments in their computing programmes is unknown. I wanted to know more about these initiatives and for participants to become aware of them also, and so these conversations were helpful in my later formulation of tasks (like historical analysis) which I will discuss in Section 5.3.3. Additionally, these informal talks revealed people's desire for more such initiatives to enhance computer science education and promote female interest in the field. Some ideas they suggested included creating short videos featuring current female computing students discussing their academic and career choices to be shared with school students. These discussions, while not discussed in detail here due to ethical considerations, guided me to engage with other key people, analyse documents and externally research the problem for effective outreach strategies. These conversations also played a role in my recruitment approach and participant interest, as elaborated in Section 4.5.

When participants were recruited and prior to workshops commencing, we knew that we were aiming to co-design an outreach initiative involving both the secondary school and the University's Department of Computing to enhance female participation in computer science. This co-design is visually represented in Figure 5.5 as two separate blank activity systems, one for each institution, linked by a cloud symbolising an initial, still-abstract concept. While this initial concept lacked specificity, the participants from both institutes shared a common understanding of boosting student interest in computer science education, especially among female students. The goal was to address the low uptake of computer science in senior years at the school and the gender imbalance in the university's computing programmes. Among the participants, few had prior experience designing outreach programmes, and none had previously participated in a Change Laboratory intervention.

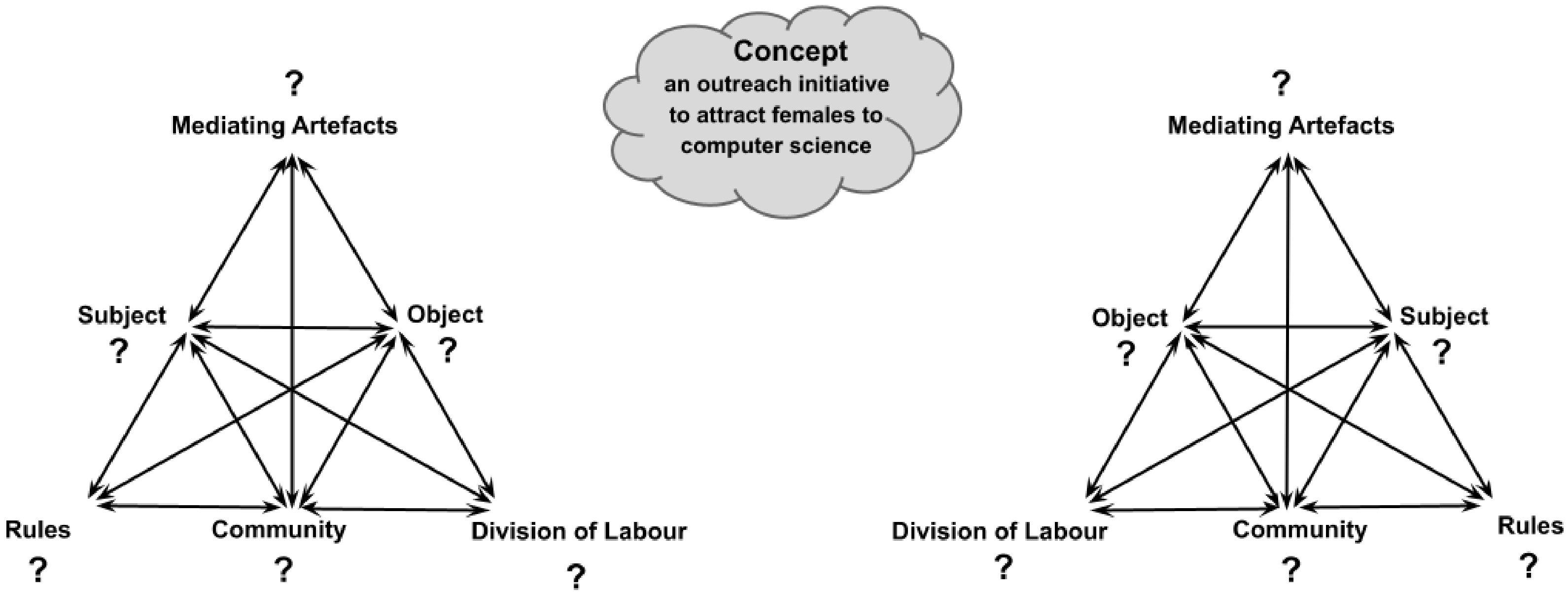


Figure 5.5: Two blank activity systems based on initial concept at the early design stage.

Prior to the first workshop, I convened an online meeting with participants from the university, the HoD and faculty members, to capitalise on the opportunity presented by the intervention (discussed in Section 4.6.1). My intention was to stimulate staff into thinking about the problem locally and beyond and to begin forming a shared idea of the object of their activity. In the months leading to the first workshop, I maintained consistent communication with the primary ICT teacher at the school, to ensure the coordination of participants from both settings. This included scheduling workshops at convenient times according to all participants' timetables and selecting an accessible online platform for hosting the workshops.

As detailed in Section 4.6.5, I performed additional preparatory tasks, including designing the first workshop and planning tasks. This process involved collecting pertinent data and creating resources to serve as mirror-data. For instance, I obtained anonymised statistics from individuals with access to share data, outlining the gender distribution among students enrolling in computing programmes within the Computing department and those studying computing subjects at the school (Figure 4.7). I also sourced and excerpted a podcast segment (Figure 4.8) for use in workshop one.

Following the pre-workshop processes just described, the subject of each activity system became known. The participants recruited from the university's Computing department, constituted a diversity and inclusion recruitment working group (DIRWG), formed for this research-intervention. Those recruited from the school were STEM teachers, specialising in STEM subjects. The decision to position the STEM teachers as the subjects in the school's activity system is based on their direct influence over students' learning experiences and their capacity to shape perceptions of computer science. As teachers, they are the ones engaging with students daily, delivering curriculum content, and creating opportunities for outreach. Their role within the classroom and school naturally positions them as central to driving the changes necessary to increase female participation in computer science. This new piece of information, combined with the evolving concept, can be represented in an updated format based on Figure 5.5, shown in Figure 5.6. I will use this format throughout the chapter to reflect any new developments or contradictions that emerge during the co-design process with participants after each workshop.

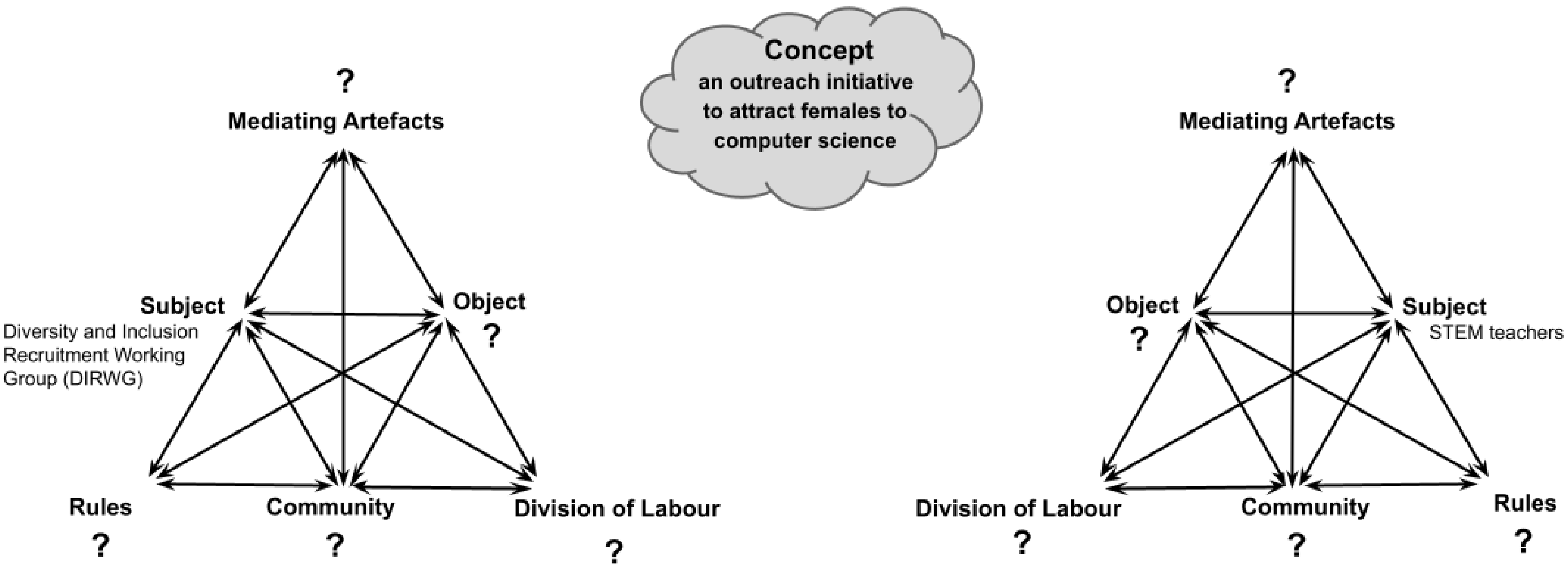


Figure 5.6: Two separate activity systems with only the initial concept and subjects known.

5.3.2 Workshop one

5.3.2.1 The design of the workshop

My intention with my design for this first workshop, as set out in Table 5.1, was to stimulate questioning which means to reject or criticise some aspects of the existing activity or wisdom (Section 3.4). In this case, I sought to make that work for this setting by including three tasks that highlighted the problem at hand and created an opportunity for participants to become acquainted and to begin dialogue.

Table 5.1: Workshop one design

	WORKSHOP ONE 04.03.2022			
	Expansive learning action: Questioning			
	First-stimuli	**Second-stimuli**	**Mirror-data**	**Social organisation**
TASK 1A	Introduce participants, the project, process, problem trying to change.	Introductory page on Notion with key points about project, process and problem.	Statistics highlighting the gender imbalance in Informatics on Bachelor programmes in Ireland and the EU.	Group (14)
TASK 1B	What are your motivations for joining this project? What are your experiences surrounding the number of female students in your classes?	Participant answers and discussions recorded on Notion pages and made available to all to serve as mirror-data.	Statistics with gender breakdown of students studying computing in both contexts presented.	Group
TASK 1C	What do you think a Computing Outreach programme for today's secondary school students needs to be effective?	Participant answers and discussions recorded on Notion pages and made available to all to serve as mirror-data.	Audio snippet to demonstrate and motivate how outreach can make a difference.	Group
	Documentation, discussion and Recording	Use Notion workspace to record discussions and ideas. Use MS Teams to host and record workshop.		

With task 1A my aim was for participant introductions, discuss the project and workspace, and highlight the problem we were looking to change. The framing of this problem was assisted by the works I carried out prior to the first workshop as described in Section 5.3.1. I would present a statistic highlighting the gender imbalance enrolling on Bachelor programmes in Informatics in Ireland and across the EU. Task 1B consisted of two questions that would question participants about their motivations for joining this project and to discuss issues and conflicts experienced in their context and highlight the problem of female underrepresentation in computer science locally. To support this, I would present local statistics with gender breakdown of students enrolling on computing programmes in the Department of Computing and the number of students studying computing subjects in the school. This would also introduce the DIRWG to some of the school's current computing offerings. I included task 1C, to provoke participants, to hear each others different ideas and to criticise existing wisdom around their standard view of what interventions might look like, especially since many previous interventions have happened in the school and university department. I also wanted to demonstrate the positive impact outreach initiatives can make, using an audio snippet to demonstrate how a secondary school outreach experience in a different school motivated a female student to pursue computer science at third level.

5.3.2.2 The progress of the workshop

Workshop one was held on MS Teams with 14 participants, with one schoolteacher unable to join due to the impact of COVID-19 on teaching resources. In a format I will reprise when describing subsequent workshops, Figure 5.7 displays an ongoing group discussion during the workshop and an introductory page on Notion with the workshop agenda, accessible through a shared link.

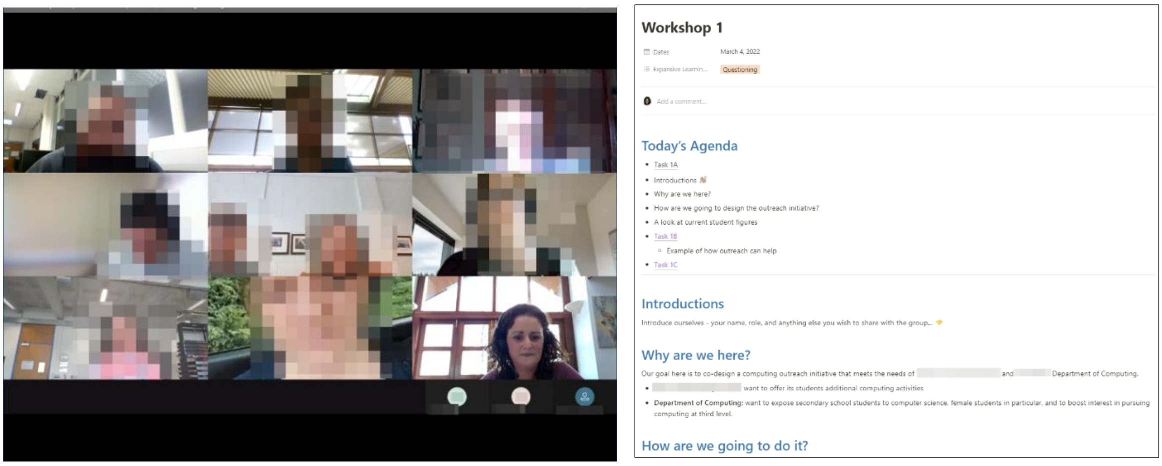


Figure 5.7: Workshop one – group discussion (left) and session agenda on Notion (right)

Task 1A revealed that the participants were from diverse roles, backgrounds and experiences. They shared their motivations for taking part in this research-intervention, aligning with a planned question in task 1B. Motivations included a strong interest in integrating computer science education into schools before higher education.

> *"I joined up because I know from my point of view from when I was in school I didn't really have much of computing in general, so I got interested to be able to give input for that and to see something hopefully change"* – Undergraduate student 3, W1

Others expressed a desire to foster greater participation in computer science, particularly among female students. For example the Head of Department (HoD) said:

> "*…in my role, as the head of department, I'm very supportive of any initiative that helps increase the participation of females. Diversity is key out there in the industry at the moment, it's in all the headlines*" - Head of Department, W1

In terms of concept development, the comment by the HoD was the first instance where *diversity* was mentioned and was later revisited by participants during discussions and debate over the importance of attracting a diverse cohort of students into computer science. This was the initial formation of a concept which would later be titled *diverse cohort of students*, shown in Figure 5.1.

Other participants, during their introductions, wished to enable a better understanding among students about what computer science is, as they believe it is heavily misunderstood by school students.

> "*we have just introduced computer science to the Leaving Cert and we have our 6th years now going through it and a lot of them didn't know what Computer Science was when they took the subject… So, I would like to create an awareness within the school so that students know what they are going into*" – Schoolteacher 1, W1

Participants also wished to make students aware of the vast opportunities in Computing for travel and to work on innovative projects. In general, they displayed a passionate commitment to creating change and promoting gender balance within the field.

I proceeded to introduce the project methodology, following the Change Laboratory approach, how the workshops would be conducted and explained the of management of project resources using Notion. The group was presented with mirror-data (Figure 5.8) showing a significant gender imbalance in third level informatics programmes, with 80% or more being male.

> At the Bachelor level in Ireland and across Europe - **80% or more** of the students enrolling or graduating in Informatics Bachelor programs **are male**.
>
> **Source:** COST Action CA19122 EUROPEAN NETWORK FOR GENDER BALANCE IN INFORMATICS (EUGAIN), March 2020

Figure 5.8: Mirror-data highlighting the gender imbalance in Informatics at Bachelor level in Ireland and the EU

Data on gender breakdown on the school computing subjects and the department of Computing's first-year enrolments on its undergraduate computing programmes were presented, as shown in Figure 5.9. Discussions were had on the statistics from both contexts, noting the low percentage of female students opting for computing at second and third levels, with the exception of the school's first year which included a compulsory computing subject. They noted that female first year enrolments at undergraduate level stood at only 15%. It was acknowledged that this is a long-standing issue globally and not just locally.

	First Year Computing (estimates)		
	Male	Female	TOTAL
2020/2021	81	81	162
2021/2022	76	76	152

	Transition Year Coding		
	Male	Female	TOTAL
2020/2021			
2021/2022	13	8	21

	Leaving Cert Computer Science		
	Male	Female	TOTAL
2020/2021	15	12	27
2021/2022	16	4	20

Academic Year	% Females
2016/17	8%
2017/18	9%
2018/19	12%
2019/20	14%
2020/21	15%

Figure 5.9: Gender breakdown in school-level computing subjects (left) and first-year enrolments in the Department of Computing's undergraduate programmes (right).

The school's statistics revealed its current computing offerings, including a compulsory computing subject for first year students, elective coding for fourth year (also known as transition year or TY) students, and an optional computer science subject for fifth and sixth year students. The ICT teacher described the syllabus and noted a lack of interest in the senior years, sparking discussions about the lack of opportunities for students to stay engaged in computing beyond first year.

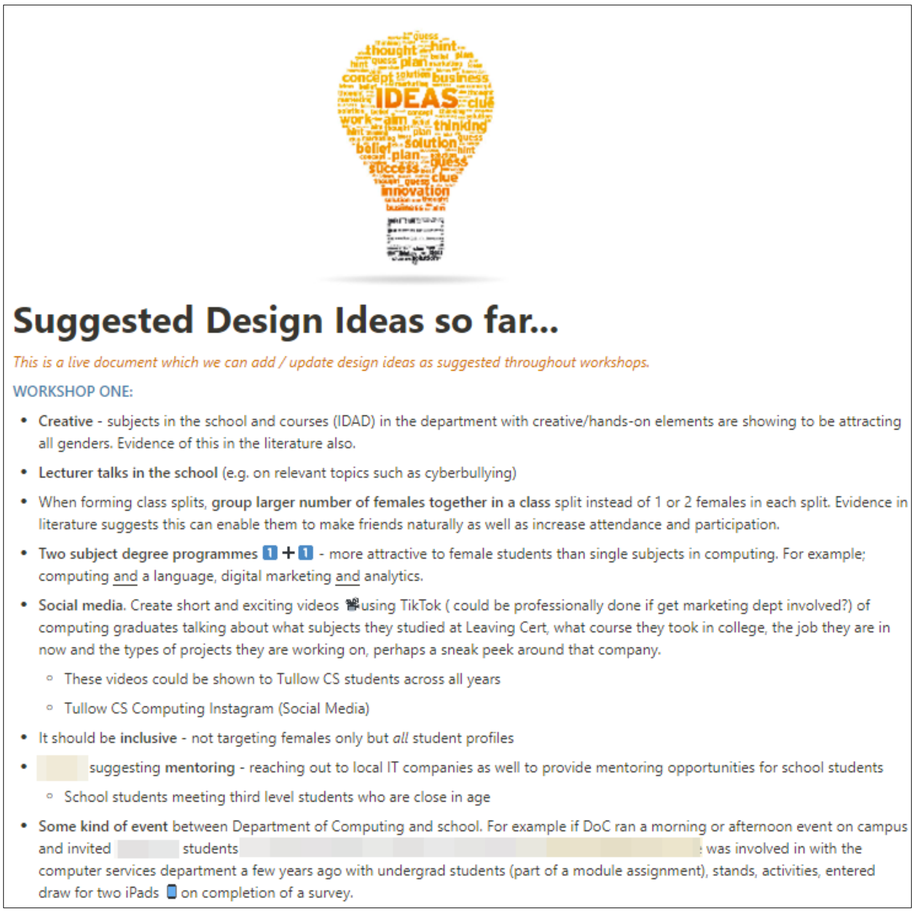
> *"… you're offering computing in first year, and then there's a two year gap before any more computing is an option. So… students that don't do TY and don't take up computer science at the Leaving Cert, that's the end of their computing experience… it's quite a difficult choice for students making leaving cert subject choices to choose computer science when they might not have done any computing in three years"* - Lecturer 6, W1

One DIRWG member questioned access to additional computing activities and resources to maintain students' interest in computing :

"how much leeway would there be for students in the second year to still keep their hand in with computing?" - Lecturer 2, W1

The group discussed the school's computing facilities, including computer labs which are heavily booked throughout the year. One STEM teacher mentioned that students are more interested in Junk Kouture, a project-based, hands-on, and creative subject that promotes sustainable fashion design. This led to discussions about the department's interactive digital art and design programme which attracts a balanced ratio of male and female students. Participants wondered if aspects of the programme could be implemented to make computing more appealing to students.

All ideas and suggestions, including these observations, were documented in the live Notion document, shown in Figure 5.10, for future referencing and modelling in subsequent workshops.



Suggested Design Ideas so far...

This is a live document which we can add / update design ideas as suggested throughout workshops.

WORKSHOP ONE:

- **Creative** - subjects in the school and courses (IDAD) in the department with creative/hands-on elements are showing to be attracting all genders. Evidence of this in the literature also.
- **Lecturer talks in the school** (e.g. on relevant topics such as cyberbullying)
- When forming class splits, **group larger number of females together in a class** split instead of 1 or 2 females in each split. Evidence in literature suggests this can enable them to make friends naturally as well as increase attendance and participation.
- **Two subject degree programmes** 1 + 1 - more attractive to female students than single subjects in computing. For example; computing and a language, digital marketing and analytics.
- **Social media.** Create short and exciting videos using TikTok (could be professionally done if get marketing dept involved?) of computing graduates talking about what subjects they studied at Leaving Cert, what course they took in college, the job they are in now and the types of projects they are working on, perhaps a sneak peek around that company.
    - These videos could be shown to Tullow CS students across all years
    - Tullow CS Computing Instagram (Social Media)
- It should be **inclusive** - not targeting females only but *all* student profiles
- [illegible] suggesting **mentoring** - reaching out to local IT companies as well to provide mentoring opportunities for school students
    - School students meeting third level students who are close in age
- **Some kind of event** between Department of Computing and school. For example if DoC ran a morning or afternoon event on campus and invited [illegible] students [illegible] was involved in with the computer services department a few years ago with undergrad students (part of a module assignment), stands, activities, entered draw for two iPads on completion of a survey.

Figure 5.10: A live document on Notion noting suggested design ideas for consideration

For task 1B, I skipped the first question as it had been covered in task 1A. For the second question, participants shared their experiences with female students in their classes, with one undergraduate student describing their own experience.

> "*I'm a second year student doing software development at the moment… In my course there is only like 2 girls and its clear to see the disparity between numbers of girls to lads… when I talked to the girls it was clear that they feel intimidated because there is so few*"
>
> \- Undergraduate student 1, W1

A lecturer shared an observation about female representation in various computing disciplines.

> "*Just what [undergraduate student 1] was saying about that second year class and how there's only two females, I'm a tutor on that software development programme. I don't know if it makes a difference but when I look at our cybersecurity programme, there certainly seems to be more females in the room*" – Lecturer 5, W1

This spurred other participants to share their own experiences, including the use of an evidence-based strategy to overcome situations where just one or two females are in a class of males.

In task 1C, I played an audio snippet (Figure 4.8) of a female sharing her positive experience with a outreach initiative that happened in her school, which motivated her to pursue CS in higher education. This led to participants providing suggestions based on personal experiences, literature, media, and workshop discussions. They emphasised the importance of making programmes engaging, accessible, relatable and utilising their interest in social media platforms like TikTok to spark interest in CS. They also suggested making the programmes hands-on and creative, allowing students to tackle real-world problems, another suggested two-subject degree programmes.

> "*In my opinion, an outreach program would need to be inclusive of all and hopefully by feeding in certain traits, like creativeness… that females will catch on*" – Lecturer 6, W1

> "*I think… it's not looking at computer science as an end in itself, but… to show how computing is important for any kind of job… So I think two subject degree programmes…*

are likely to be much more attractive to female students rather than single subjects in computing" – Lecturer 2, W1

In terms of concept development, the comments by lecturer 2 and lecturer 6 were some of the early instances where *inclusive* was mentioned and was later revisited by participants during discussions and debate over the importance of designing a curriculum that includes inclusive content, diverse examples and relevant projects. This was the initial formation of a concept which would later be titled *inclusive computing curriculum*, shown in Figure 5.1. The ICT teacher mentioned that students would appreciate the opportunity to meet or work alongside university students of similar age, perhaps in a mentoring capacity. Suggestions to accomplish this included a mentorship programme provided by undergraduate student members of the department's Women in Technology society or some kind of event between both institutes.

"*something that we could tease out… whether it's a resource that's available online or… some sort of event between IT Carlow and Tullow. I'm not really sure, but I think there's certainly something that we could look at there definitely*" – Lecturer 6, W1

Before the workshop concluded, tasks were assigned to gather data on the Department of Computing's recruitment and outreach initiatives, and existing computing activities for students in the school. Two lecturers offered to take the lead on the department's data collection, while all five STEM teachers offered to collate the data in their own setting.

5.3.2.3 Implications for the design

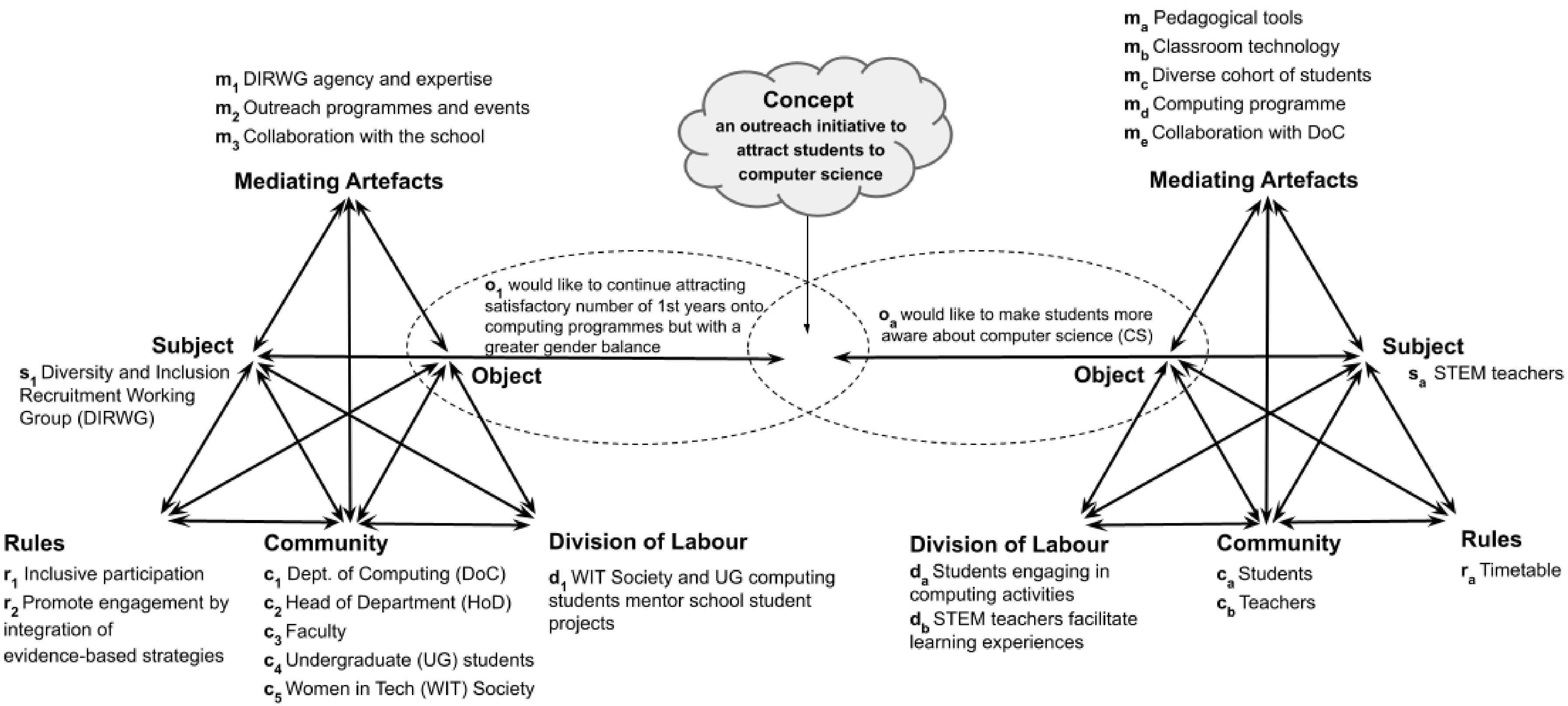


Figure 5.11: Design implications arising from workshop one from questioning current practices and considers the design in relation to current practices

This section describes the design implications arising from workshop one. Design implications will be referenced using their corresponding label (e.g., design implication m_1, design implication r_2) as denoted in Figure 5.11. I will continue this labelling format throughout the thesis. These implications arose from questioning current practices and considers the design in relation to current practices. The reasons for these design choices will now be described.

At this point, participants agreed that the design should:

- build on, and adapt if necessary, the existing pedagogical tools in the school such as teaching approaches (m_a).
- aspire to be inclusive (r_1) by exposing all students to a variety of sub-disciplines in computing and cater for the diverse needs and interests of all learners (m_c). Regardless of the format or type of computing programme designed (m_d), and drawing on the DIRWG's agency and expertise (m_1), it should be engaging, accessible, relatable and utilise their interests.
- embed evidence-based strategies (r_2) proven in the literature to attract and support minority groups such as females (e.g., two-subject degree programmes, grouping females in smaller lab groups, teacher support (c_b, d_b), project-based, hands-on, creative, develop solutions for real-world problems (d_a).
- include outreach programmes and events (m_2) such as mentorship programmes between second-level students (c_a) and undergraduate computing students (c_4) and WIT society (c_5, d_1).
- include a collaboration involving both partners such as guest lecturer (c_3) talks in the school (m_3 and m_e).
- allow the university computing department to continue attracting satisfactory numbers of first years onto computing programmes but with a greater gender balance (o_1).
- assist the school in making students more aware about computer science (o_a).

Discussions during workshop one centred on the existing activity systems and the identification of key contradictions and dilemmas that impede progress. The overarching goal was to leverage these identified contradictions as valuable insights when crafting a new and improved computing education in the school. By addressing these dilemmas head-on in the design process, the objective was not only to overcome the existing obstacles but also to enhance computing education practices.

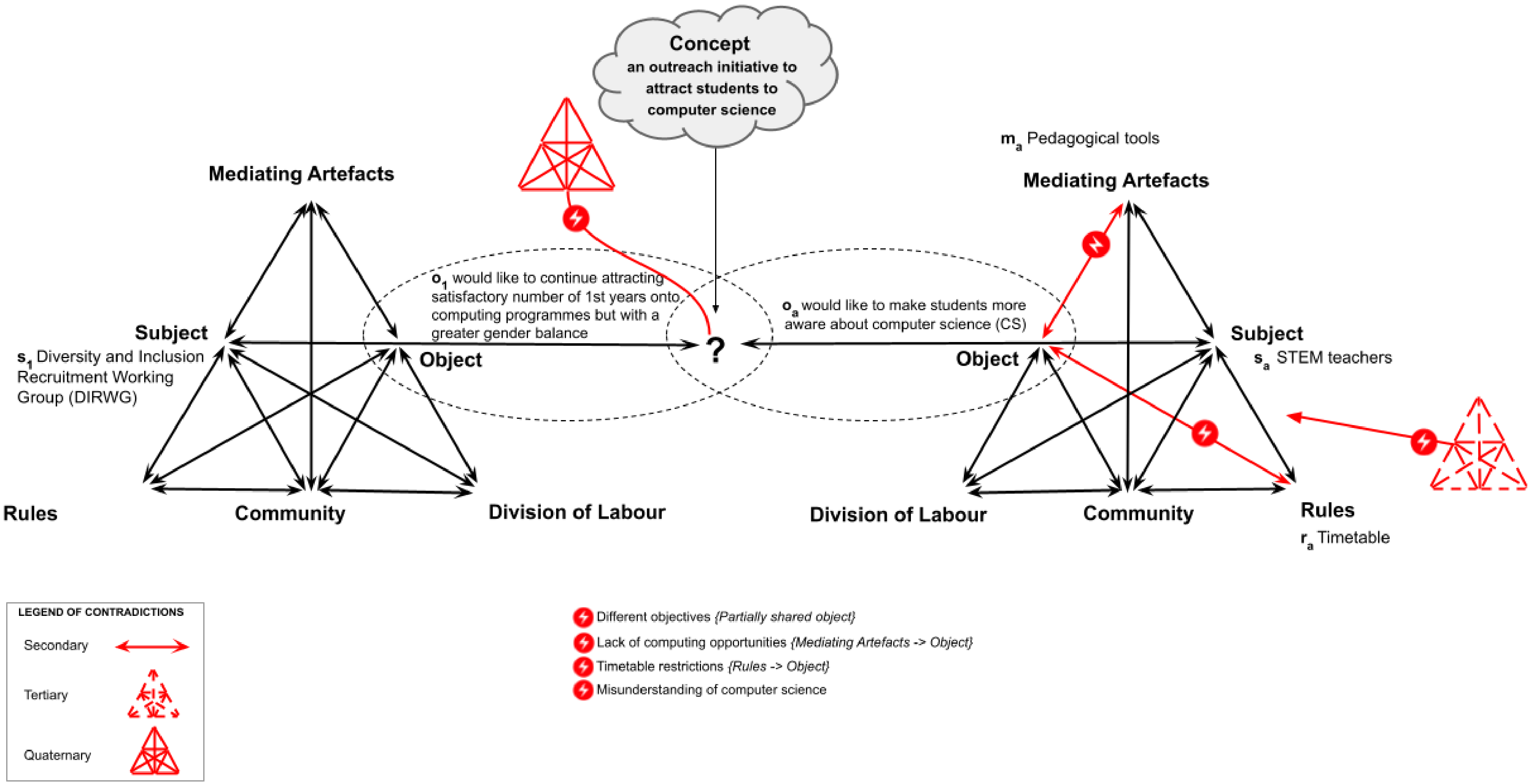


Figure 5.12: Contradictions arising from workshop one from questioning current practices and considering the design in relation to current practices

Four contradictions were identified during workshop one. These are contradictions that exist in the current activity system and at this early stage of the design process have not yet addressed. Participants hope to overcome these contradictions during the design process so that they do not exist in the new activity system. They can be seen labelled and illustrated in red in Figure 5.12.

- *Different objectives*. This quaternary contradiction occurs between the objects of the two interacting activity systems involved. While both share a partially common object, to increase awareness and participation in computer science, each also pursues additional system-specific objectives that may not fully align. For example, the school is constrained by its timetable structure and national curriculum requirements, while the university operates on different academic cycles and has recruitment-oriented priorities. These differing objectives and associated rules (e.g., academic calendars, assessment periods) can create tensions when attempting to jointly plan outreach activities, as changes that serve one system's priorities may inadvertently conflict with the other's.
- *Lack of computing opportunities*. This secondary contradiction occurs within the school's activity system between mediating artefact m_a (pedagogical tools) and the object o_a (to increase student awareness and engagement in computer science). The absence of computing classes in second and third year means that the tools and resources available are insufficient to maintain continuity of learning. This misalignment limits sustained engagement and conflicts with the object of building long-term interest, particularly among female students, before senior-cycle subject selection..
- *Timetable restrictions*. This secondary contradiction occurs within the school's activity system between rule r_a (timetable) and the object o_a. The rigid scheduling rules restrict access to computing resources during the academic year, making it difficult to implement additional outreach sessions or integrate computing into other subjects. As a result, opportunities to work towards the object are constrained by these institutional rules.
- *Misunderstanding of computer science*. This tertiary contradiction occurs within the school's activity system between the object of the current new practice (to deliver the existing curriculum, often focused on ICT skills), and the object of the proposed new practice (to give students a broader, more accurate understanding of computer science). Teachers observed that many students, particularly females, view computing narrowly as "just coding". This misconception creates tension between the existing delivery (which

inadvertently reinforces limited perceptions) and the desired future practice (which would present computing as a diverse, creative, and collaborative discipline).

5.3.2.4 Reflective research diary notes on workshop

When the workshop ended on Teams, I took some time to reflect on the session and documented my thoughts in a reflective research diary, as illustrated in Figure 5.13, following the guidelines outlined in Section 4.7.3. Overall, I was highly satisfied with the first workshop and believed it served as a strong starting point, fostering engagement among all participants. The workshop went as planned, except for participants providing their motivations for joining this project during their introductions, which was a question I had planned later in task 1B. I believe this shows the participants' eagerness to get started on this project. The mirror-data I had prepared and used proved to be effective in presenting the problem and facilitating fruitful discussions among the participants.

In terms of stimulating *questioning*, the expansive learning action for this workshop, I believe it was successful. As outlined in Section 3.4, questioning is the process of critically examining and rejecting aspects of the existing activity or accepted wisdom. The participants began engaging with the data and statistics, and their responses indicated that they were actively reflecting on the issues in their current practices. For instance, they questioned the lack of opportunities for students to stay engaged in computing at school, raised concerns about timetable constraints, and critically discussed the low participation of females in computer science programmes. These reflections demonstrate that the participants were already challenging the status quo, which corresponds well to my goals of promoting questioning at this point.

Additionally, the discussions generated thoughtful critiques of traditional outreach approaches and highlighted potential contradictions that would need to be addressed in future design efforts. This suggests that the workshop was successful in encouraging participants to think beyond existing frameworks, setting the stage for deeper inquiry in subsequent workshops.

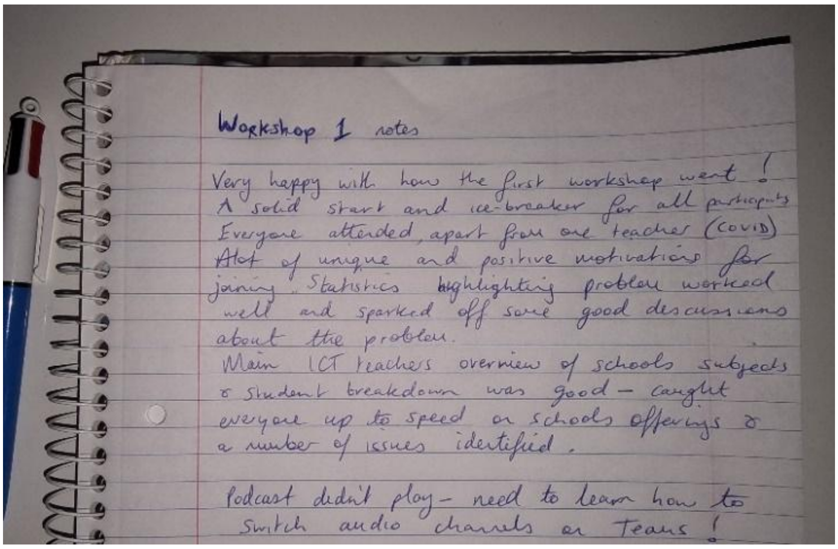


Figure 5.13: Sample of reflective research diary notes for workshop one

5.3.3 Workshop two

5.3.3.1 The design of the workshop

My intention with my design for workshop two, as outlined in Table 5.2, was to stimulate historical analysis and actual-empirical analysis by investigating and examining both the present activity and earlier activities that have led to the current methods of practice (Section 3.4). To effectively implement this approach within the workshop's setting, I incorporated five tasks.

Table 5.2: Workshop two design

	WORKSHOP TWO 11.03.2022			
	Expansive learning action: Historical Analysis, Actual-Empirical Analysis			
	First-stimuli	**Second-stimuli**	**Mirror-data**	**Social organisation**
TASK 2A	What computing initiatives has the school tried in the past? Did it work well or not?	Initiatives mapped to blank timelines or tables on new wiki page on Notion. This will later serve as mirror-data.	Participants to answer queries on past practices (“live mirror”)	Group (10)
TASK 2B	What computing activities are currently in place in the school?	List made on new wiki page on Notion. This will later serve as mirror-data.	Participants to answer queries on current practices (“live mirror”)	Group

TASK 2C	What types of recruitment/outreach has the department done in the past? Did it work well or not?	Initiatives mapped to blank timelines or tables on new wiki page on Notion. This will later serve as mirror-data.	Participants to answer queries on past practices ("live mirror")	Group
TASK 2D	What types of recruitment/outreach is the department currently doing?	List made on new wiki page on Notion. This will later serve as mirror-data.	Participants to answer queries on current practices ("live mirror")	Group
TASK 2E	*Activity System Model Activity:* What do you think the elements of the AS diagram are for current CS education (school) or recruitment (DoC) practices?	Discuss and complete blank AS diagram in respective group.	Visual material on activity System with descriptions of terms and examples.	Two groups in breakout rooms
	Documentation, discussion and Recording	Use Notion workspace to record discussions and ideas. Use MS Teams to host and record workshop.		

Tasks 2A, 2B, 2C and 2D involved questions to provide participants with an understanding of past and ongoing computing initiatives at the school. The goal was to avoid designing an outreach intervention that replicated ineffective strategies or did not align with the school's resources or culture. Familiarising participants with past or ongoing initiatives by the Department of Computing would allow them to appreciate their effectiveness and provide STEM teachers with opportunities to explore potential benefits for their students.

Task 2E was designed to acquaint each sub-group with the activity system diagram through actual-empirical analysis. I believed that dividing participants into two sub-groups, one for each activity system, would enhance comprehension by allowing each sub-group to analyse their respective activity system alongside members of the same context. Therefore, I planned to split them into two sub-groups: one consisting of DIRWG participants and the other comprised of STEM teachers. Each sub-group would discuss and identify elements relevant to their current practices, filling in a blank activity system diagram which I had prepared. This would promote reflection and provide a visual representation of components and relationships within their activity systems, deepening understanding before moving to the design stage.

5.3.3.2 The progress of the workshop

The second workshop on Teams involved 10 participants. I started by sharing the workshop agenda (Figure 5.14) and recapping on discussions from workshop one. I gave a second demonstration on how to access and create wiki pages on the project workspace on Notion.

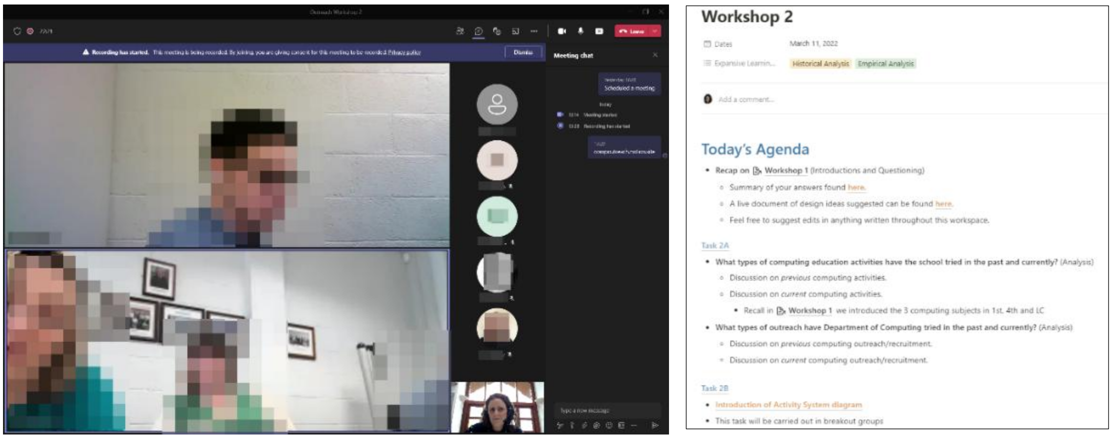
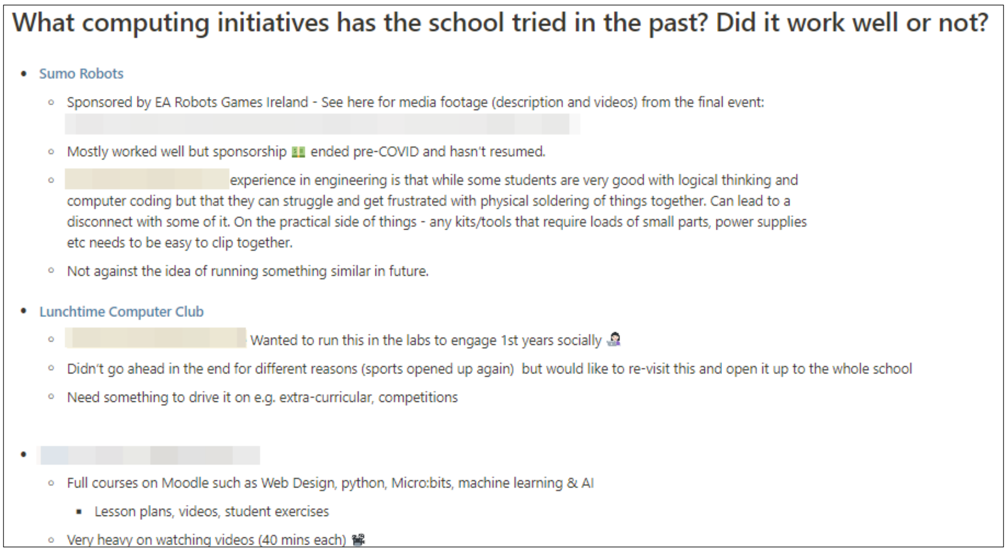


Figure 5.14: Workshop two–group discussion (left) and workshop agenda on Notion (right)

For task 2A, the STEM teachers discussed past computing activities (Figure 5.15), including a sumo robot project that lost sponsorship, a lunchtime computer club that failed to take off in the school, and a MOOC offering online computing courses, that heavily relied on video content and lacked the interactive elements necessary to keep students motivated to learn.



What computing initiatives has the school tried in the past? Did it work well or not?

- Sumo Robots
  - Sponsored by EA Robots Games Ireland - See here for media footage (description and videos) from the final event:
  - Mostly worked well but sponsorship 💵 ended pre-COVID and hasn't resumed.
  - experience in engineering is that while some students are very good with logical thinking and computer coding but that they can struggle and get frustrated with physical soldering of things together. Can lead to a disconnect with some of it. On the practical side of things - any kits/tools that require loads of small parts, power supplies etc needs to be easy to clip together.
  - Not against the idea of running something similar in future.
- Lunchtime Computer Club
  - Wanted to run this in the labs to engage 1st years socially
  - Didn't go ahead in the end for different reasons (sports opened up again) but would like to re-visit this and open it up to the whole school
  - Need something to drive it on e.g. extra-curricular, competitions
-
  - Full courses on Moodle such as Web Design, python, Micro:bits, machine learning & AI
    - Lesson plans, videos, student exercises
  - Very heavy on watching videos (40 mins each)

Figure 5.15: Past computing initiatives at the school (anonymised)

A DIRWG member inquired about the school's history of hosting CoderDojo classes, which the teachers confirmed they had not done before. The member shared a positive experience at

DojoCon, a CoderDojo conference involving the Department of Computing. CoderDojo is a global, volunteer-led movement of free, open coding clubs for young people aged 7 to 17, known for fostering interest and motivation in computer science. This discussion prompted suggestions of organising an event between the partners, as mentioned in workshop one.

> "*… if you want to really like get a club or something going, you need to have something at the end of it for them… you're nearly buying their motivation. Like if you can give them something to work towards, like a trip away… a day out of school. Yeah, that will definitely keep them involved*" – Schoolteacher 4, W2

The STEM teachers showed great enthusiasm for the idea and highlighted the advantages of having a goal or event to motivate and engage students.

> "*Having the college name over it would be massive motivation for them [students]. Like, there's a bigger world out there for them as well*" – Schoolteacher 1, W2

Participants suggested organising a cybersecurity morning at the university campus, with the DoC inviting school students. The event would include fun activities to raise awareness about cybersecurity, with undergraduate computing students volunteering to participate.

For task 2B, STEM teachers were asked to share information about ongoing computing activities for students. The activities, documented on a new Notion wiki page during the workshop (Figure 5.16), included the existing computing subjects, a web design competition, and the use of physical computing. The web design competition had mixed student interest, despite the availability of prizes, but teachers viewed it as an opportunity to introduce first-year students to new topics. One STEM teacher mentioned using Micro:bits, physical computing devices, in their engineering classes.

What computing activities are currently in place in the school?

- As discussed in Workshop 1. Computing subjects are currently offered to all 1st years (mandatory), 4th years (optional) and the Leaving Cert Computer Science (5th and 6th years).
- Micro:bits
- Web Design competition (deadline St. Patrick's Day)
  - This is optional and being run with 3 groups:
    - Junior: 1st, 2nd and 3rd years
    - TY: 4th years
    - Seniors: 5th and 6th years
  - money prize 💰
  - Mixed interest levels
  - Introducing 1st years to something they wouldn't get in another class.

Figure 5.16: Current computing initiatives in the school

With task 2C, the DIRWG discussed the DoC's outreach and recruitment initiatives, as depicted mapped onto a timeline on Notion (Figure 5.17), including lecturer school visits, the GameJam games development competition, summer camps, Coder Dojo coding classes, a women in computing and engineering seminar for Transition Year students, and a women in technology society. It was noted that some initiatives were mapped approximately and that these initiatives occur annually.

Timeline of Department of Computing's outreach activities ···

Date	Name	Details
2008	Lecturer visits to schools	• promoting computing courses, Q&A • sporadic times throughout the academic year • Difficult to gauge its impact on enrolments
2010	GameJam	• Participation restricted to UG students • Age Restrictions: 18+ only. Majority male.
2010	Technology Summer Camps	• Open to senior cycle students starting from TY. i.e. those sitting the Leaving Certificate the following two years. • Web Design (HTML and CSS), Programming, Hardware and Networking ◦ create apps, develop an interactive web site, build a computer network, assemble computer hardware • 1 week camp every June until 2021 (structure changing in 2022 - possible 2 x 2-day camps of different focus e.g. robotics, gaming and creative camps) • Approximately 20 - 30 places • Supported by the Higher Education Authority • Averaged 84% male between 2013-2018 • Is there data to show how many go on to study computing?
2013	Women in Computing & Engineering Seminar	• Annual event on campus • Transition year students • female-only schools invited? • Q&A with panel of UG/PG engineering and computing students
2014	Coder Dojo	• Started originally in a local school in 2012 • open to 8-16 year olds. • 2 hr classes on Tuesday evenings from 6:30pm to 8:30pm (Feb - March)

Figure 5.17: Timeline of the Department of Computing's past and ongoing outreach activities

A STEM teacher noted that the summer camps and the seminar specifically target transition year student, and that this may be too late to effectively attract students to computer science.

> *"… if we wait til transition year, the horse has nearly bolted… because what happens is a lot of our females end up in what could be perceived as more female dominant subjects. And if they're doing well in it, you're going to have a very hard sell to get them to come to computer science or engineering. Then by the time it comes to fifth year, because parents are so focused on their kids doing well, they'll say you're guaranteed… whatever grade in that subject, you're not changing. And there's a little bit more pressure when the end game is CAO points, and that's what parents will be looking at, sometimes to the point where they say, I don't care whether you like the subject or not, you're good at it, so stick it out."*
>
> – Schoolteacher 4, W2

The STEM teacher suggested providing outreach activities, such as mini versions of the seminar or the GameJam competition, to first-year students and generate interest in computing before they complete their taster program. The taster programme is where the school offers all students on arrival to first year, a timetable that allows them to 'taste' particular subjects for a short duration. The teacher emphasised that engaging first-year students at this stage would more likely yield more interest than targeting TY students.

The concern about the absence of computing subjects in second and third years was revisited. This lack of continuity in the curriculum could lead to students not opting for computer science at the Leaving Certificate level due to insufficient knowledge, confidence and experience compared to other subjects.

> "*… we were kind of saying last week that if there's something that we could do to keep second and third years engaged, be it a lunchtime club in the computer lab or something that we can keep computing at the forefront of their mind before they choose subjects for leaving cert. So I think whatever it is that we do eventually design, we should try to target those students in particular."* – Lecturer 6, W2

Participants agreed that it is crucial to offer computing subjects beyond first year. The main ICT teacher highlighted her experience with first-year students eager to continue their studies in computing, but disappointed to learn there were no computing subjects available for them to progress into. A DIRWG member suggested simplifying Leaving Cert computer science projects for second and third-year students.

> "*it's not just learning computing, for the sake of computing or programming, but it's actually giving them some kind of insight into what a leaving cert project is like and preparing them for it*" – Lecturer 2, W2

In response to the question in task 2D, the DIRWG confirmed that all the events and initiatives described for question three are still actively implemented by the department.

Task 2E introduced the activity system model and divided participants into two breakout rooms where each group received a blank activity system diagram. Figure 5.18 illustrates the active engagement of the DIRWG in their breakout room.

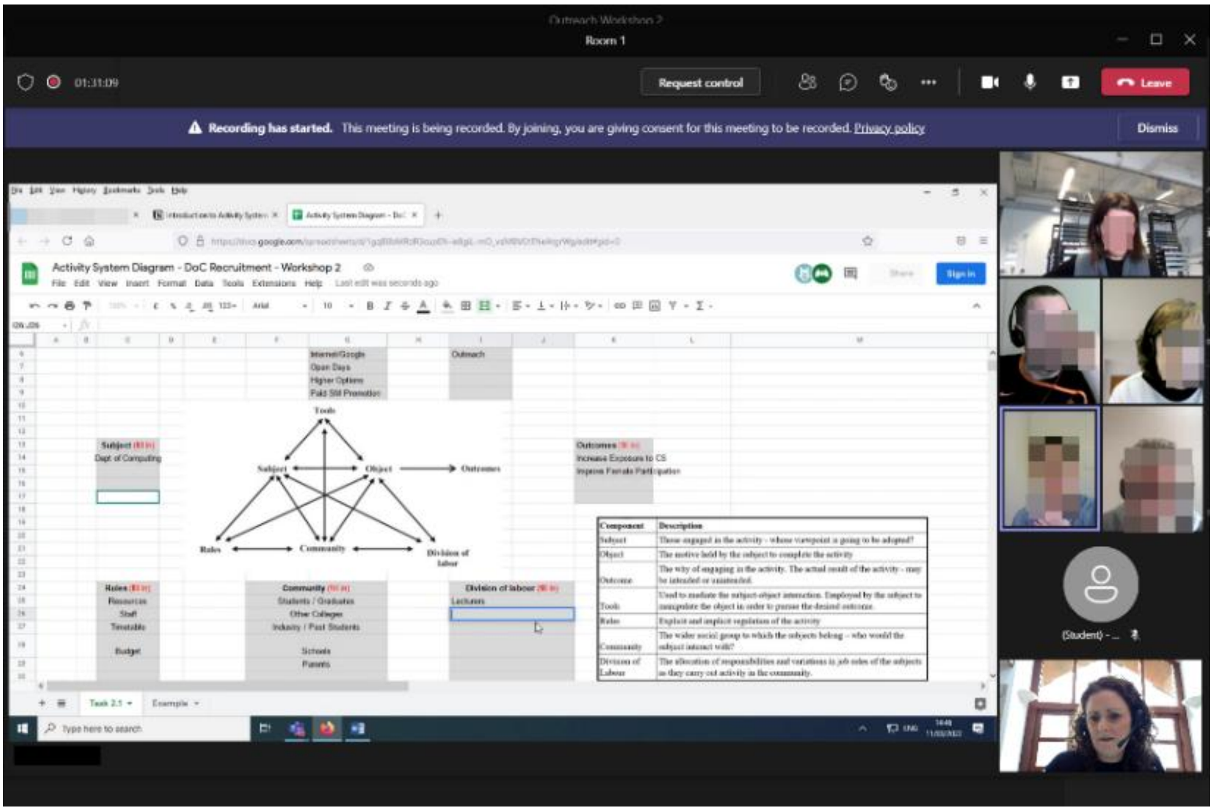


Figure 5.18: DIRWG breakout room developing an activity system diagram for Task 2B

During their breakout room discussions, participants contributed ideas to a shared diagram, capturing elements of their respective activity system. Figure 5.19 shows the activity system diagram completed by the STEM teachers who mapped the elements for their current teaching and learning practices in Computing in the school.

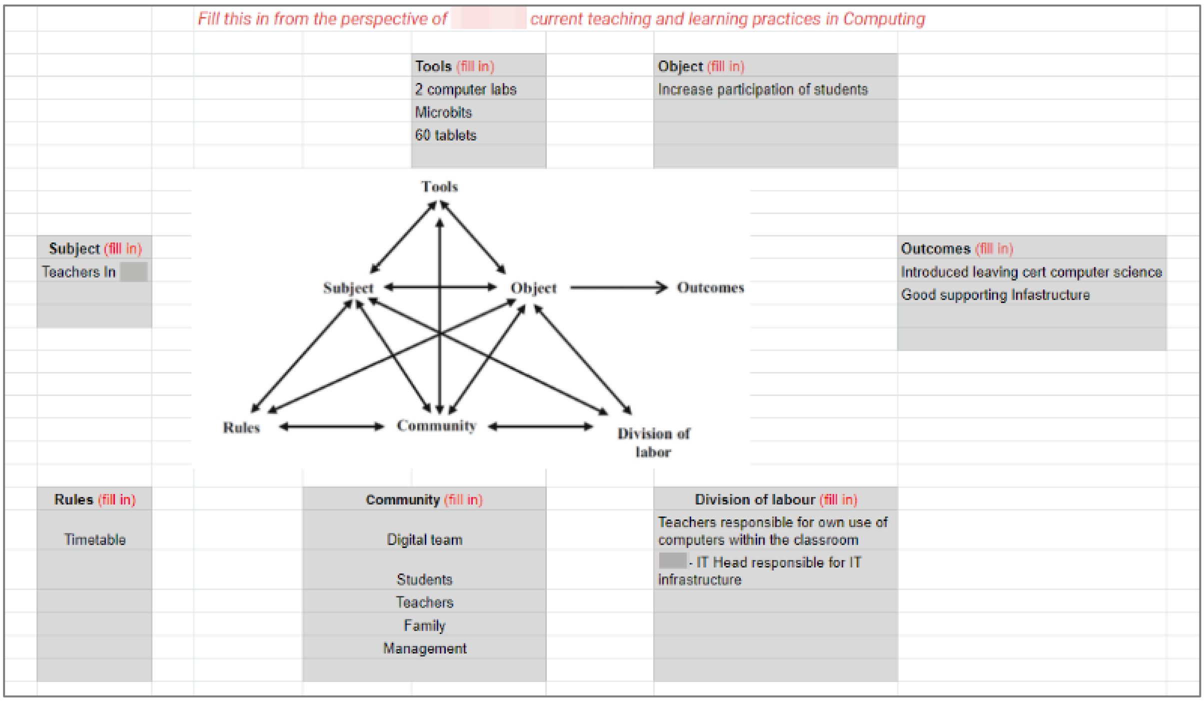


Figure 5.19: The activity system diagram mapped by the STEM teachers for Task 2B

Figure 5.20 shows the activity system diagram completed by the DIRWG who mapped the elements for their current recruitment practices in the Department of Computing.

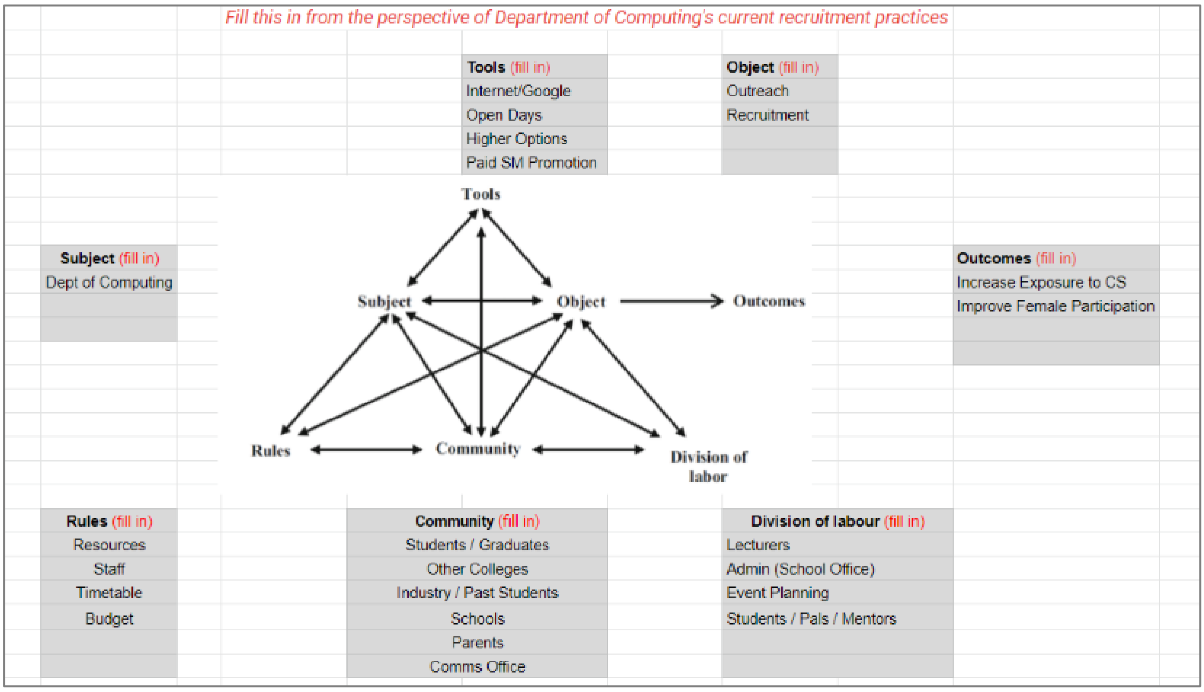


Figure 5.20: The activity system diagram mapped by the DIRWG for Task 2B

Following workshop two, certain participants took initiative to prepare for workshop three. The STEM teachers held a meeting to discuss specific topics. Additionally, a DIRWG member conducted independent research on the Coder Dojo event mentioned during the workshop.

5.3.3.3 The implications for the design

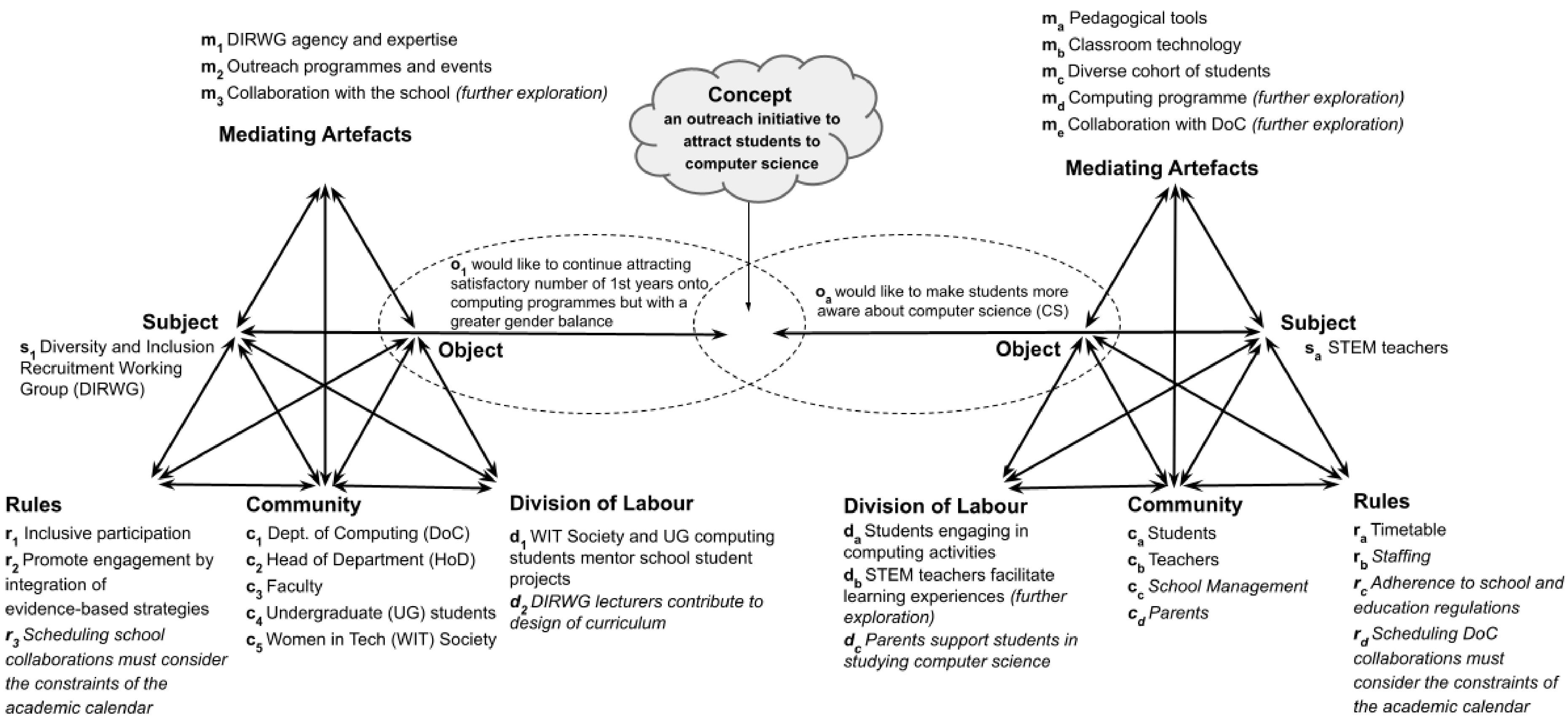


Figure 5.21: Design implications arising from workshop two

Figure 5.21 visually represents the design implications resulting from workshop two, which are distinguished from workshop one's design implications using italicised text. I will continue this format throughout the remaining workshops, by highlighting any new design implications in italicised text. These new implications arose in consideration with current practices and their rationale will now be explained.

When participants were considering the design in this workshop:

- they explored design implications m_3 and m_e again. Further suggestions were made with regards to the inclusion of collaborations (e.g. trip away from school, a cyber awareness morning on campus), featuring the college name, as motivation for students to work towards.
- they explored design implication m_d further, by contemplating the inclusion of new computing interventions like a lunchtime club, a computer society, simplified versions of LCCS projects (designed with the expertise of DIRWG lecturers (d_2)) to provide opportunities for all students to stay engaged in computing, as long as any intervention included adhered to school and education regulations (r_c).
- they agreed any events (m_2) and new interventions included would need consideration in terms of logistics and timing during the academic calendar of both activity systems (r_3 and r_d).
- they agreed school management (c_c), parents (c_d) and staff (r_b) would need consideration in terms of their influence over subject availability and student subject choices.
- they explored design implication d_b further. Further suggestions were made with regards to how STEM teachers can facilitate learning experience.

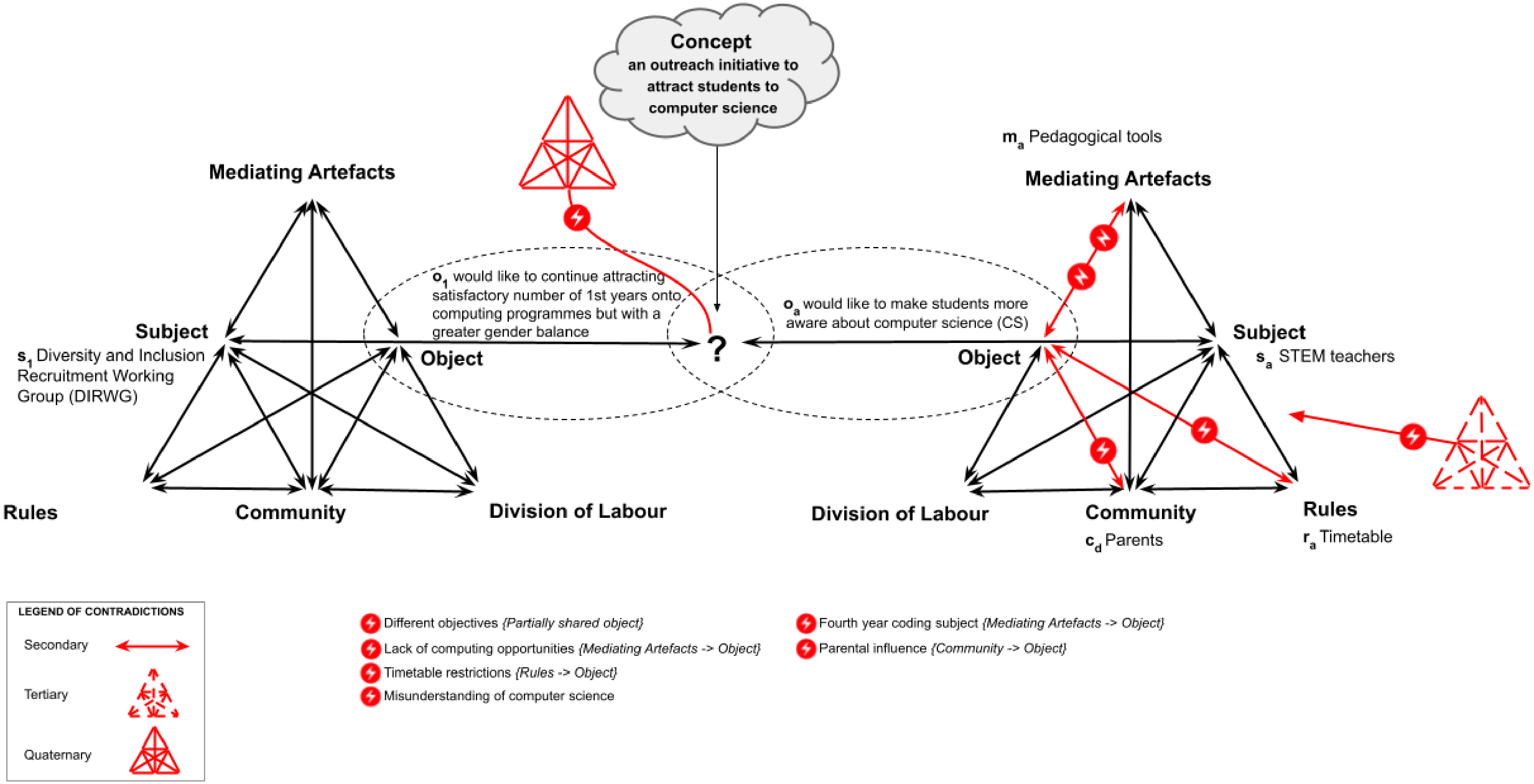


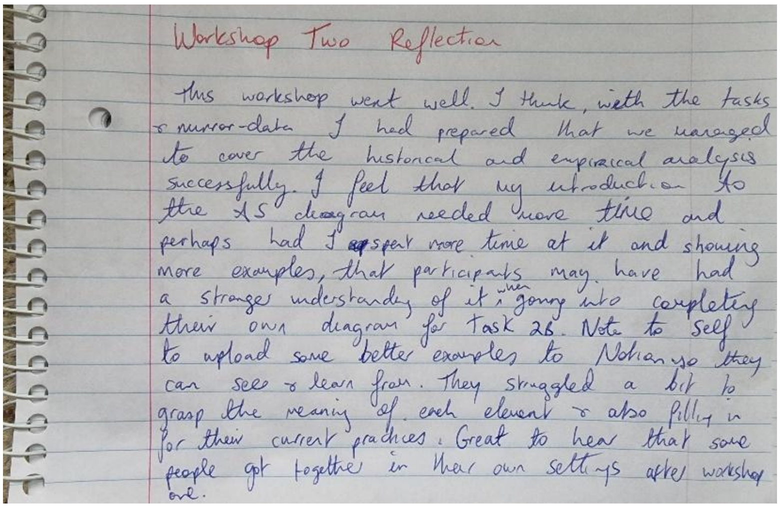
Figure 5.22: Contradictions identified at this stage of the design process when considering the design implications and current practices

Two contradictions were identified in workshop two and no previous contradictions were resolved when considering design implications and current practices. The contradictions identified at this stage of the design process are highlighted in Figure 5.22. Participants hope to overcome all of these contradictions during the design process so that they do not exist in the new activity system. The contradictions identified in workshop two are described as follows:

- *Fourth year coding subject.* In the existing activity system, coding is available as an optional subject in fourth-year, but it is not widely chosen. Participants discussed how this option occurs too late in student's educational journey to significantly influence their subject choices for the scenario cycle. The contradiction here is not simply about timing and popularity, rather, it reflects a misalignment between mediating artefacts m_a, in this case, the tools and curriculum structures intended to foster computing interest and the object o_a of making students more aware of and engaged with computer science. When computing is introduced only at a late stage and in a non-compulsory format, the tools fail to adequately support the object of the activity. This systemic tension limits the outreach potential of the existing curriculum.
- *Parental influence.* This is a secondary contradiction that occurs between the community (c_d), particularly parents, and the object (o_a) of increasing student awareness and interest in computer science . Participants, especially STEM teachers, observed that parental attitudes can act as a gatekeeping mechanism. Parents may encourage students to prioritise subjects perceived as more likely to yield high grades or align with traditional career paths. Since computing is not available in second and third year, parents may not see it as a serious or viable subject and may therefore steer students away from choosing the LCCS subject later on. This contradiction highlights a tension between the broader social influences surrounding the learner and the intended developmental goals of the outreach initiative.

5.3.3.4 Reflective research diary notes on workshop

Immediately following workshop two, I documented my thoughts in my research diary, a sample of which is depicted in Figure 5.23. While I felt the workshop effectively stimulated historical analysis, with participants actively discussing past computing initiatives (e.g., the sumo robot project and the unsuccessful lunchtime computer club), I realised that my introduction to the activity system diagram was too brief. Dedicating more time to explain this, along with additional examples, would have enhanced their understanding and engagement. Throughout the workshop, both historical analysis and actual-empirical analysis were evident as participants examined past initiatives and assessed the effectiveness of current practices. These discussions created an environment where participants could critically evaluate what worked and what needed re-evaluation. I recognised the need to adjust the design for the next workshop to include an additional task focused on the activity system diagram. This would help participants better understand its elements and encourage them to explore tensions, which I believed would benefit subsequent tasks.


Workshop Two Reflection

This workshop went well. I think, with the tasks & mirror-data I had prepared that we managed to cover the historical and empirical analysis successfully. I feel that my introduction to the AS diagram needed more time and perhaps had I spent more time at it and showing more examples, that participants may have had a stronger understanding of it when going into completing their own diagram for Task 2B. Note to self to upload some better examples to Notion so they can see & learn from. They struggled a bit to grasp the meaning of each element & also filling in for their current practices. Great to hear that some people got together in their own settings after workshop one.

Figure 5.23: Sample of reflective research diary notes for workshop two

5.3.4 Workshop three

5.3.4.1 The design of the workshop

My intention with my design for workshop three, as outlined in Table 5.3, was to continue focussing on actual-empirical analysis and then to move to modelling. To achieve this, I designed three tasks.

Table 5.3: Workshop three design

	WORKSHOP THREE 25.03.2022			
	Expansive learning action: Actual-Empirical Analysis, Modelling			
	First-stimuli	**Second-stimuli**	**Mirror-data**	**Social organisation**
TASK 3A	To consider tensions within the AS diagrams.	Review the AS diagrams completed in workshop two and continue discussions.	Participants completed activity system diagrams (outcome of task 2B) Interacting model of both diagrams.	Group (10)

TASK 3B	*Identify school's needs.* What are the schools current needs/wishes from this outreach initiative with the university?	Generate a list of school's needs on new wiki page on Notion.	School participants to answer queries on current needs ("live mirror").	Group
TASK 3C	*Modelling challenge.* Can you come up with a design for an outreach initiative that meets the needs identified in task 3B? You have 35-40 minutes to finalise your design and then come back and present to group.	Participants can use whatever tools or platforms they wish to describe or illustrate their proposed design.	Outcome of tasks 1A, 1B, 1C, 2A, 2B, 3A, 3B available on Notion.	Two groups in breakout rooms Group
	Documentation, discussion and Recording	Use Notion workspace to record discussions and ideas. Use MS Teams to host and record workshop.		

Task 3A was designed around actual-empirical analysis and was for participants to review the activity system diagrams from workshop two, and to identify dilemmas between components, with the aim of gaining deeper insights into their current activity systems. Task 3B aimed to continue with actual-empirical analysis by identifying the school's specific needs in computer science education. The STEM teachers were emailed the question ahead of the workshop to gather their input. This information would serve as valuable input for the next task, task 3C. With task 3C, my aim was to begin modelling and to divide participants into two groups where they would be given a time period to generate designs that aligned with the identified needs from task 3B. Throughout this task, my plan was for participants to be reminded of the outcomes of previous tasks through mirror-data, ensuring continuity and coherence in the design process.

5.3.4.2 The progress of the workshop

In the third workshop, attended by 10 participants on Teams, I began by displaying the activity system diagrams completed in the previous workshop (Figure 5.24). We engaged in a discussion regarding the elements and their relationship within each activity system.

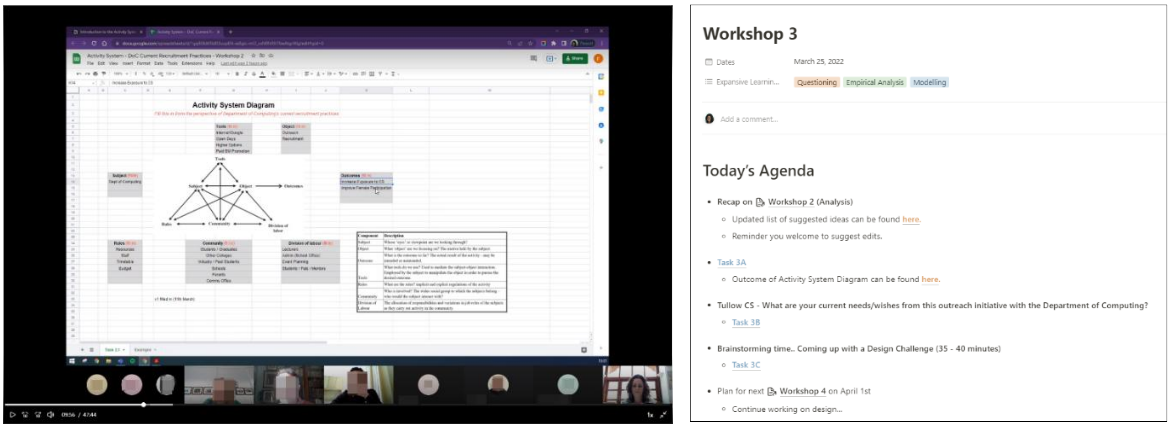


Figure 5.24: Workshop three –group reviewing an activity system diagram for Task 3A (left), workshop agenda on Notion (right)

Task 3A presented activity system diagrams from workshop two, introducing the concept of tensions and providing examples. Participants discussed potential tensions and issues within their current practices, such as staff allocation for open events and budgeting for promotion. STEM teachers recalled including the timetable as a rule in their activity system, in workshop two. They identified tensions within their activity system, including the timetable for computer labs, due to full bookings as previously discussed in workshop one. Since workshop two however, they collaborated to explore possibilities and found a vacant slot for incorporating more computing education. Task 3B involved STEM teachers discussing outreach initiative requirements and desires. I had created a new wiki page on Notion to collect and display responses, as shown in Figure 5.25.

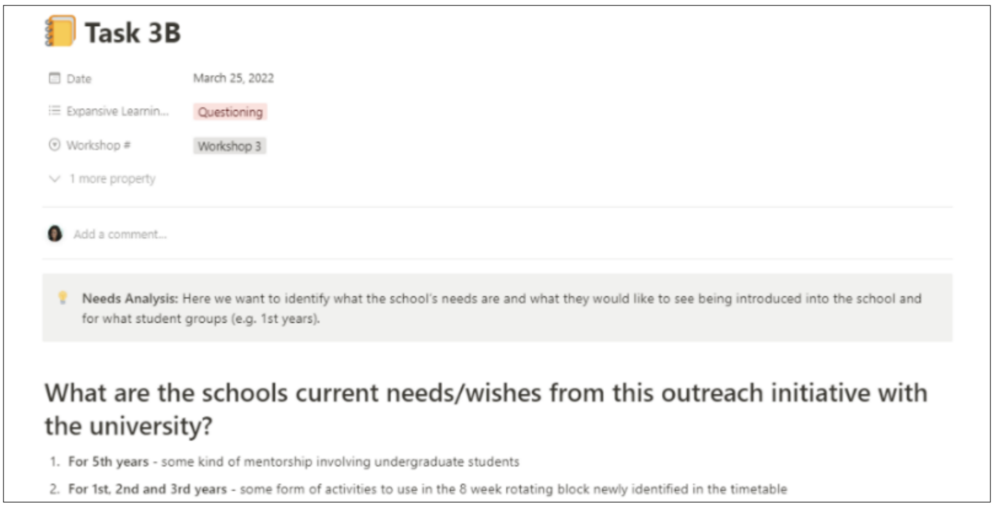


Figure 5.25: Wiki page on Notion for task 3B

The STEM teachers expressed two wishes. They expressed interest in having undergraduate students from the Department of Computing visit the school and interact with students. After our first workshop, she had discussions with her students about computing education in the school and received major interest regarding the opportunity to engage with undergraduate computing students as mentors, especially during project work. This led to discussions among the group about the feasibility of arranging visits by undergraduate students to the school.

> "*we have this volunteer awards program within the institute, which once a student has done so many hours of volunteering, they can apply for it… something else for their CV… I don't see any reason why that couldn't be expanded out to something like mentors for your school… if it means getting a minibus to send them out there for a lab class… I'll be happy to support that*" – Head of Department, W3

The group emphasised the need for careful consideration of timing when seeking students volunteers for school visits.

> "*the timing of such a thing is important because…right now you wouldn't have much hope of getting too much help from 2nd, 3rd or 4th year students, because they've got so many deadlines... For 1st year students, things are going to change slightly with semesterisation, because they don't have any traditional final exams and are more flexible*"
>
> – Head of Department, W3

The second need identified by the STEM teachers was then discussed.

> "*… with the 1st, 2nd and 3rd year 8-week rotation slots, if we could get some kind of programme that we could easily deliver on repeat. So say 1st years are eight groups, and they get eight classes, and then they switch to another group. So it'd be on a cycle under their well-being class called personal development. They do a certain amount of computers in that already but it's not very gripping, so if there could be something that would allow them to get a taste of what computer science is… I think that would really work… if 1st year started off basic and… 2nd year be a bit more advanced and then again in 3rd year, so… they'd have a sample every year. I think they'd be ready to choose it in 5th year.*"
>
> – Schoolteacher 1, W3

I asked the undergraduate students in attendance on their thoughts from a student perspective about the mentorship programme being considered.

"I would be interested if it was the right time… I don't think my school ever done anything where we had, like students from colleges come to our school. But I think that would be beneficial… to be able to talk to like people and what they are doing in their course at the moment. It'd just be easier for me to like relate to them."

– Undergraduate student 1, W3

Task 3C involved participants designing an outreach initiative that addressed the identified needs from task 3B. Figure 5.26 shows a screenshot of the ongoing workshop while the task brief is being presented to participants. The task brief and links to previous tasks on Notion were provided for reference. To ensure a diverse range of perspectives, I divided the entire group into two smaller groups comprising teachers, lecturers, and undergraduate students. Each group was assigned to a separate breakout room on Teams and given 35-40 minutes to finalise their design before returning to the main room to present it to the entire group.

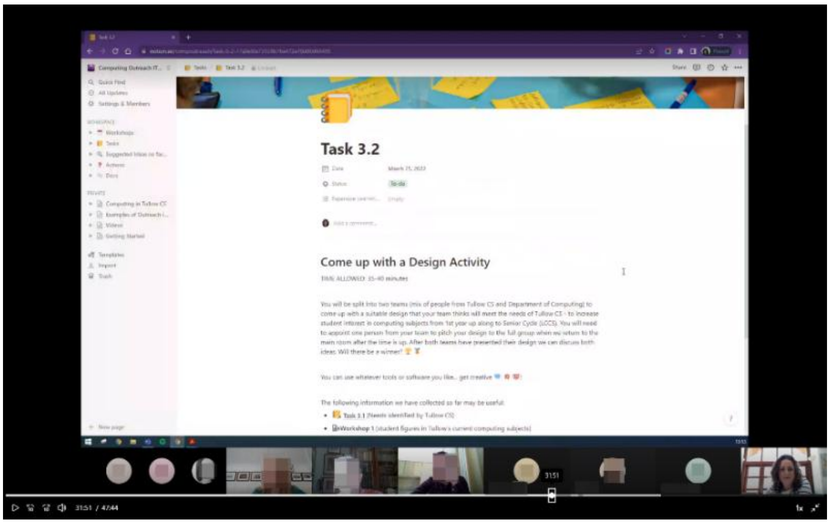


Figure 5.26: Workshop Three – introducing group to task 3C on Notion

During the activity, I actively engaged with both breakout groups (Figure 5.27), providing assistance and observing their progress. Once the allotted time was reached, all participants reconvened in the main room on Teams.

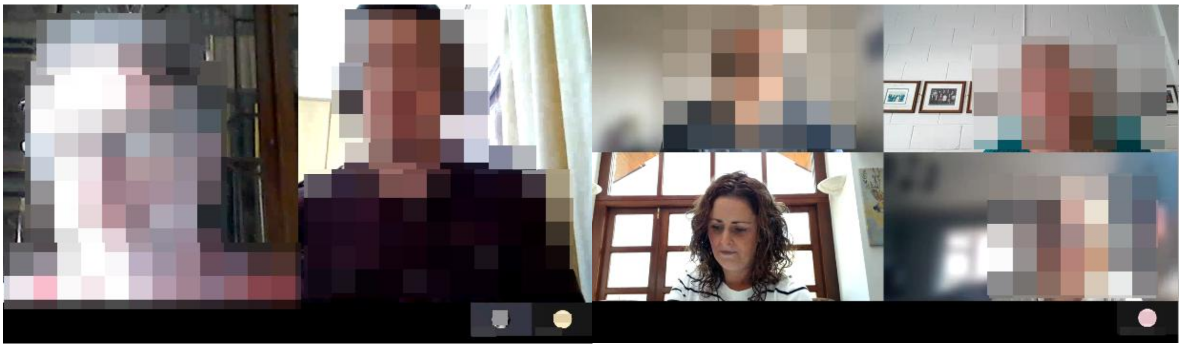


Figure 5.27: Breakout room one (left) and breakout room two (right) working on task 3C

The representative from breakout room one pitched a design focused on utilising the 8-week rotating block in the computer lab. They proposed delivering short computing subjects to first, second and third year students during this time, with the option to choose projects aligned with their interests. Undergraduate students from the Department of Computing would visit the school to mentor the students during their projects. The design also included two site visits; one where Department of Computing staff and undergraduate students would present project options at the school, and another where students and staff from the school would visit the university campus to showcase their completed projects. This site visit would also include a tour of the campus and informative talks from current and former computing students. Additionally, the design highlighted the importance of considering the age and gender of the individuals involved. It proposed seeking sponsorship from a marquee company to generate interest among school students and aimed to present computer science is its true form.

> "*we need to be careful that whatever we do, however we sell it, that we are true to what computer science is all about. We don't want to attract students by giving them a false understanding of what computing is*" – Lecturer 4, W3

In terms of concept development, this was one of many instances where enabling students to get a true sense and understanding of computing was mentioned. This added to the eventual formation of the concept titled *show the varied and true nature of computer science*, as introduced in section 5.2.

The representative from breakout room two presented a design focused on a mentoring initiative and an 8-week short computing course. Lecturer 2 presented their mentoring idea as follows:

> "*some ideas we were bouncing around… were not limited by time and budget, so we have some blue sky thinking. And it's to try to maintain the relationship between Tullow and IT*

Carlow… apart from asking students who are at IT Carlow to help out with mentoring, it's also… asking graduates from Tullow college who are studying [computing] in IT Carlow to be involved… so they can go back and share their experiences… We talked about the possibility of building a requirement… of students who are out on work placements with companies, especially if… local to the area. And maybe companies will be happy to do that if in exchange for sponsorship, their name is… highlighted as helping out with and investing in the community… also involving the departments 1st and 2nd years who would be more closely aged to… school students as well." – Lecturer 2, W3

Schoolteacher 1 outlined the second component of their group's idea, which involved an 8-week taster course in computing.

"*When [Lecturer 3] talked about the world CoderDojo event he'd been at and the different activities, that could be very interesting. For the eight weeks… you could cover cybersecurity, how to choose the correct password, so on so forth… we were kind of trying to find something that could really… engage them. So I don't know what we could do in that short time to prepare them for fifth year computer science. I think it'd be nice to give them a glimpse of what's happening but in a smaller place*" – Schoolteacher 1, W3

The group proposed offering students a preview of the LCCS curriculum by providing simplified versions of the projects they would encounter in the actual Leaving Cert examination. The projects would gradually increase in difficulty as students' progress from first year to third year.

"*… it's trying to find something that they really remember or really engage in. And it's not just something that's delivered to them… you really have to get them going every single week. But I don't want to bring anything in that's too over their heads as well, that's too big for them to digest. So I think that's the tricky part*" – Schoolteacher 1, W3

The full group engaged in discussions, and the second group showed interest in specific elements of the first group's design. Some examples discussed were:

"*What did you think of the idea [schoolteacher 1] that the others had there, about your students presenting at IT Carlow?*" – Lecturer 1, W3

"*Loved it. I think that'd be fantastic. I think they would love that.*" – Schoolteacher 1, W3

DIRWG members discussed the possibility of gathering feedback from school students about the proposed design ideas. One lecturer suggested creating a diverse list of project ideas, simplified versions of Leaving Cert projects, to cater to different student interests. To facilitate the design progress, the DIRWG planned to generate project ideas for the next workshop. The main ICT teacher would present these ideas to the students and collect their feedback.

The workshop concluded with plans to explore both proposals in the next workshop. Participants volunteered to gather information about the CoderDojo programme mentioned, and for the DIRWG to send a list of possible projects to STEM teachers for consideration with students.

5.3.4.3 The implications for the design

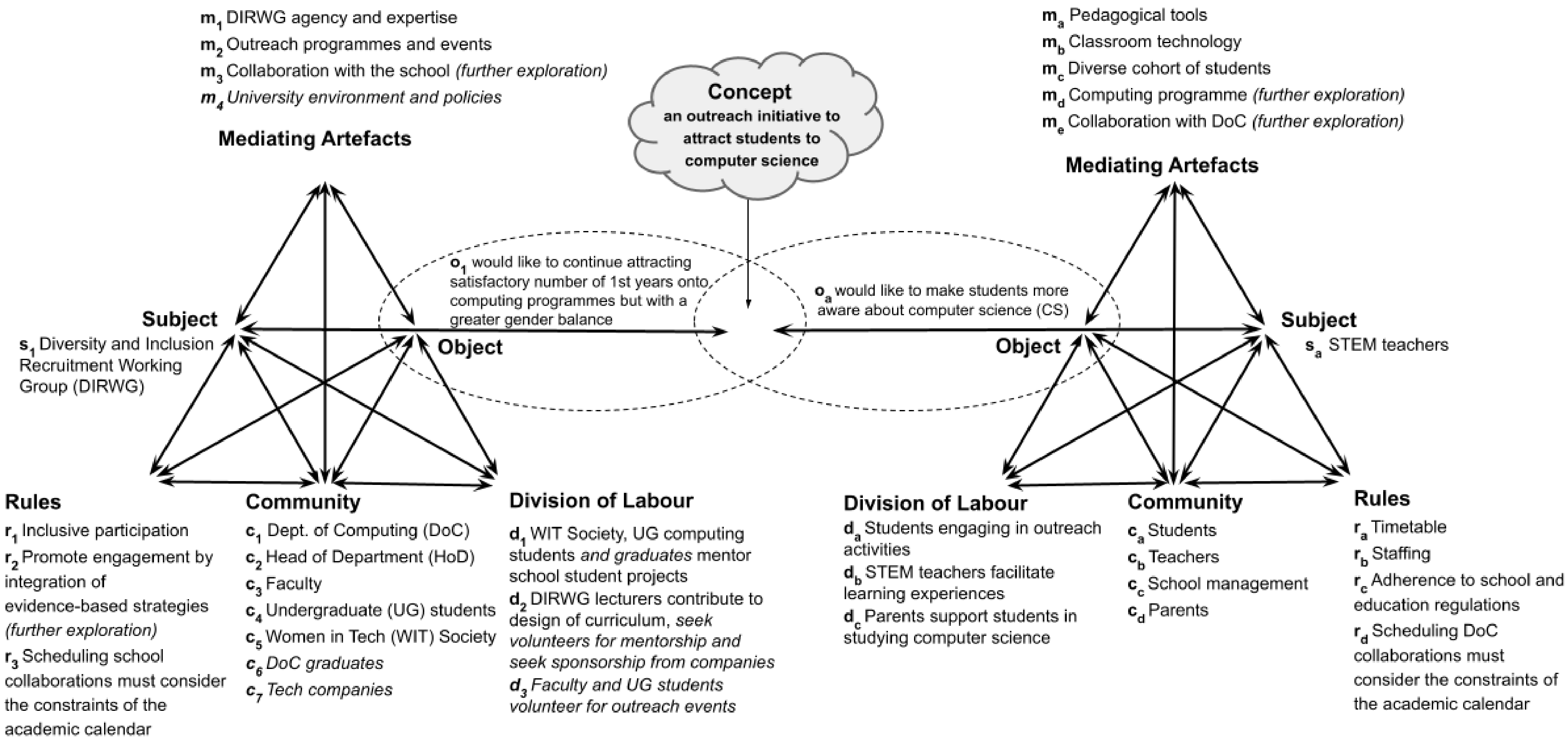


Figure 5.28: Design implications arising from workshop three

Figure 5.28 illustrates the design implications resulting from workshop three in italicised text. These implications arose when considering design implications and current practices and their rationale will now be explained.

When participants were considering the design in this workshop:

- they explored design implication m_2 again. Further suggestions were added for a mentorship programme where undergraduate students would be recruited by DIRWG lecturers (d_2) to interact in a mentoring capacity with school students at the school, ideally during project work.
- they explored design implications m_3 and m_e again. It was proposed that the type of collaboration involving both partners could be two site visits: one where lecturers and students visit the school (d_3) and one where school students would visit the university campus (d_a). They explored the options of including a tour of the university campus and informative talks from current (c_4) and former (c_6) computing students. Additionally, participants proposed seeking sponsorship (d_2) from a local tech companies (c_7).
- they explored design implication m_d again. It was proposed that the design should include utilise the existing 8-week taster courses in the school to include courses in computing for 1st , 2nd and 3rd years. They highlighted they need to integrate evidence-based strategies (r_2) as discussed in a previous workshop, into the taster courses.

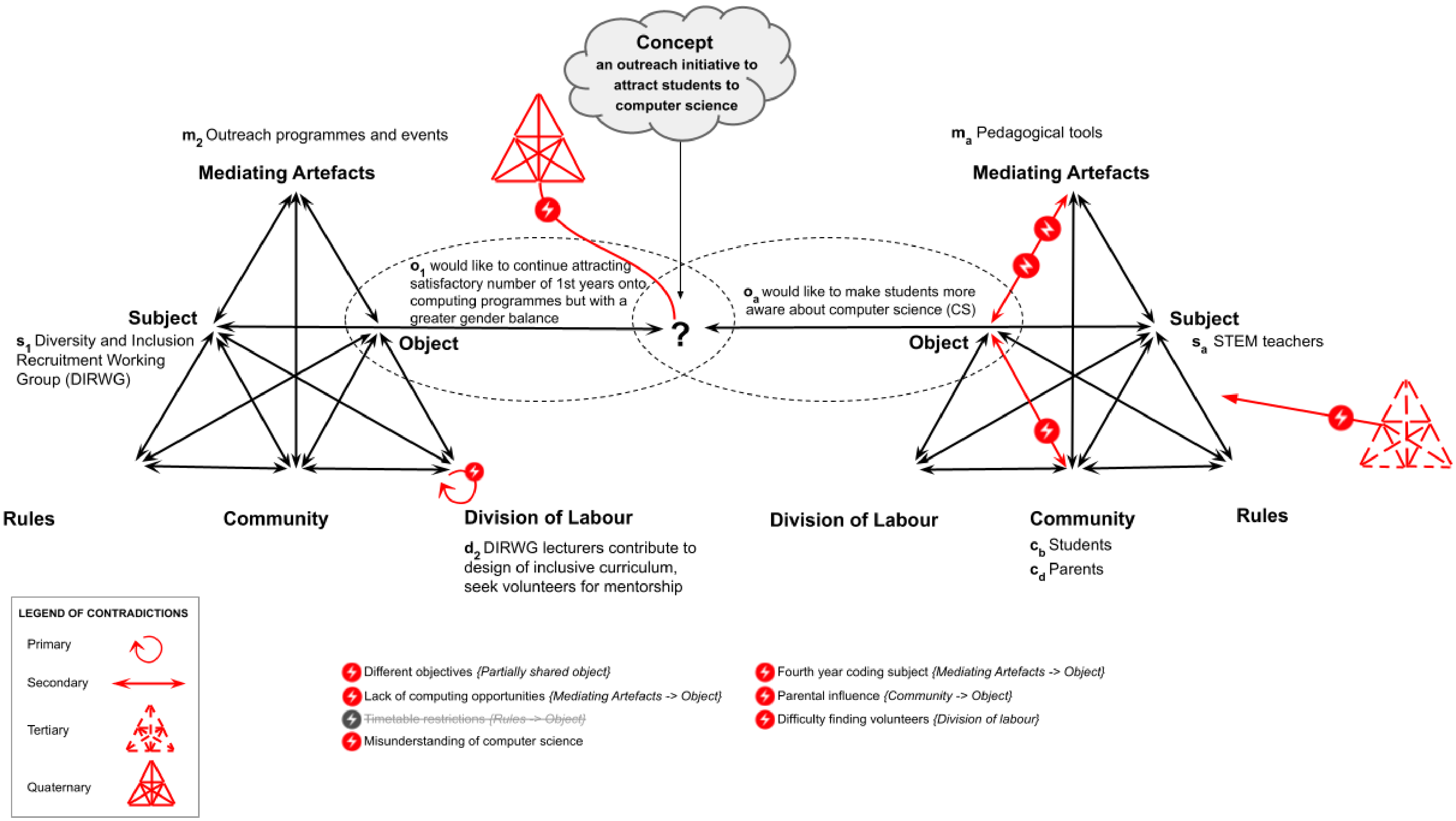


Figure 5.29: Contradictions (existing and resolved) at this stage of the design process, considering design implications and current practices

One new contradiction was identified at this stage of the design process, and one contradiction identified previously was resolved. These are highlighted in Figure 5.29. Participants hope to overcome all contradictions during the design process so that they do not exist in the new activity system. The contradictions identified and overcome in workshop three are described as follows:

- *Timetable restrictions.* This secondary contradiction occurs within the school's activity system between rule r_a (timetable) and object o_a (to increase student engagement in computer science). Under the existing timetable, there was no available slot to introduce additional computing lessons. This structural rule conflicted directly with the object by preventing the addition of new activities that could build sustained interest. The contradiction was subsequently resolved between workshops two and three, when STEM teachers secured dedicated timetable hours for additional computing, thereby aligning the rules more closely with the object. In Figure 5.29, this resolved contradiction is shown with strikethrough text and grey colour and it will be removed from subsequent diagrams. This formatting will be used consistently throughout the remainder of this chapter.
- *Difficulty finding volunteers:* This primary contradiction occurs within the division of labour element of the university computing department's bespoke outreach activity system. The Diversity and Inclusivity Recruitment Working Group (DIRWG) relied on voluntary contributions from undergraduate students to act as mentors, and from lecturers to help plan, coordinate and deliver outreach events. However, these roles competed with existing academic workloads and commitments, creating tension between the expectation to contribute to outreach and the capacity to do so. This internal misalignment within the division of labour threatened the sustainability of the mentorship programme, as the necessary human resources were not consistently available to meet the object of the activity system.

5.3.4.4 Reflective research diary notes on workshop

Immediately following workshop three, I recorded my thoughts in my research diary, a sample of which is shown in Figure 5.30. I felt that the inclusion of task 3A, focused on actual-empirical analysis, was necessary and that participants may even benefit from more time and additional tasks in future to explore tensions and dilemmas within their current activity systems more thoroughly. During this task, participants engaged in meaningful discussions, identifying tensions between system components such as staff allocation and lab scheduling, which is a core aim of actual-empirical analysis, exploring current practices to uncover underlying contradictions.

For task 3C, I was extremely pleased with the first stimulus used. The participants showed great enthusiasm and appeared highly motivated to propose new designs. Witnessing both groups access and utilise mirror-data effectively to inform their designs was particularly satisfying, as it reinforced the connection between prior analytical tasks and the creative process. Modelling, which is about designing future practices and testing potential solutions, was evident as participants collaboratively crafted outreach initiatives to address the identified needs.

After listening to both groups pitch their designs, I decided that a more impactful approach for the next workshop would be to generate visual representations of the proposed designs. This would provide a clearer, more tangible starting point, rather than relying solely on verbal or textual explanations.

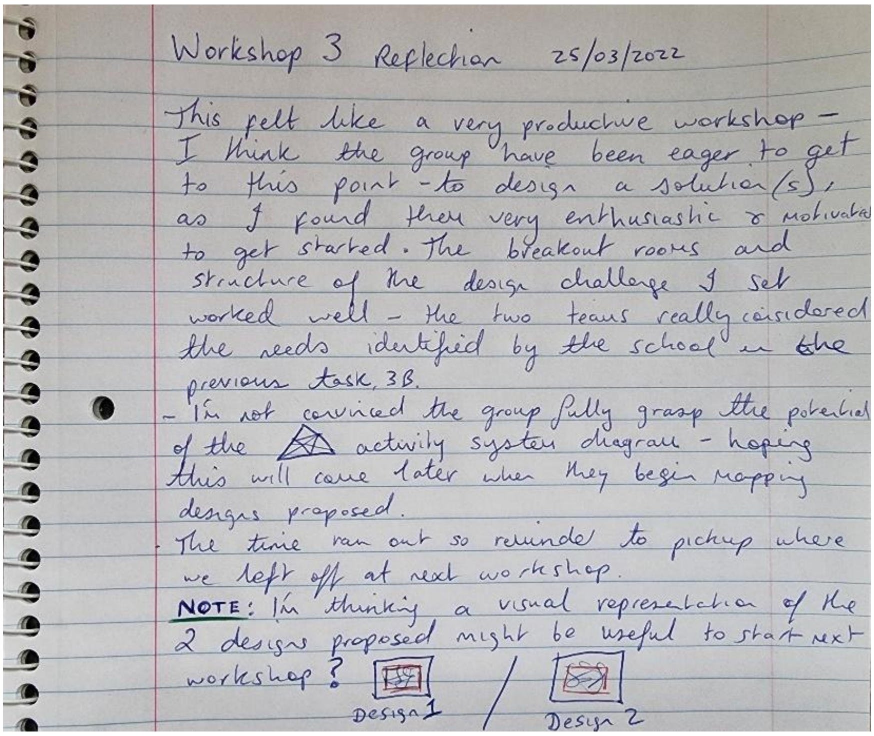


Figure 5.30: Sample of reflective research diary notes for workshop three

5.3.5 Workshop four

5.3.5.1 The design of the workshop

My plan for workshop four, as set out in Table 5.4, was to continue modelling and examining the designs. I sought to make that work by including task 4A, which would ask participants to examine the two designs proposed in workshop three. To facilitate this, I prepared graphical representations of each design pitched in workshop three. The aim was to evaluate each group's design and determine which elements should be pursued or if any new ideas should be added.

Table 5.4: Workshop four design

	WORKSHOP FOUR 1.04.2022			
	Expansive learning action: Modelling, Examination			
	First-stimuli	**Second-stimuli**	**Mirror-data**	**Social organisation**
TASK 4A	Continue modelling by examining and refining the designs proposed at the previous workshop	Update proposed design on team workspace	Graphical representations created to show the proposed designs (outcome from task 3C) and the outcome of all previous tasks accessible from Notion	Group (9)
	Documentation, discussion and Recording	Use Notion workspace to record discussions and ideas. Use MS Teams to host and record workshop.		

5.3.5.2 The progress of the workshop

Nine participants joined the fourth workshop on Teams, as displayed in Figure 5.31. One teacher had to withdraw from the intervention due to other commitments.

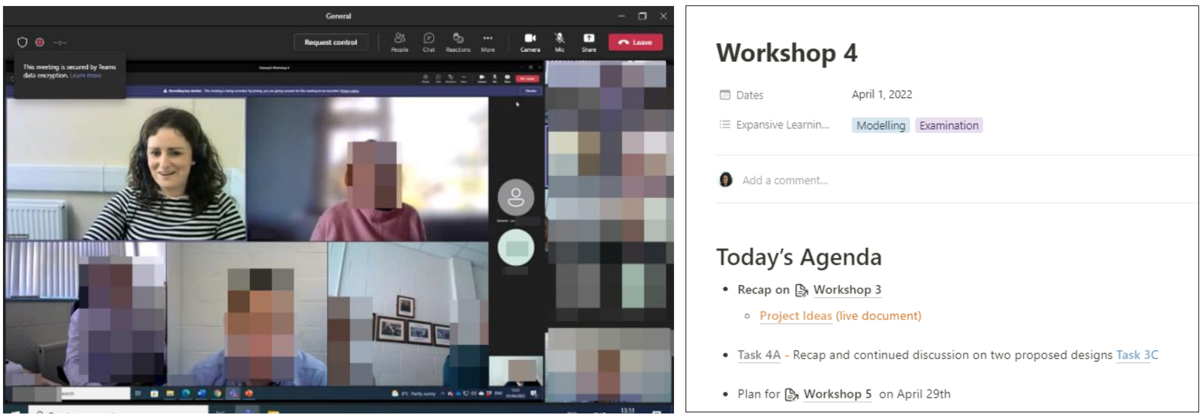


Figure 5.31: Workshop four – group discussion (left), workshop agenda on Notion (right)

The workshop began with task 4A, which aimed to continue modelling by way of continued discussions from workshop three, regarding two proposed designs from task 3C. Graphical representations of the designs (Figure 5.32) were presented on the screen to facilitate more effective discussions compared to text-based descriptions.

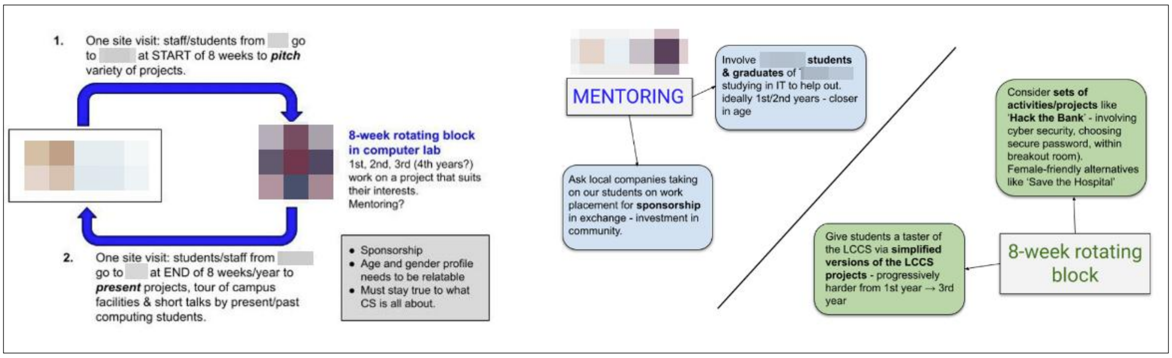


Figure 5.32: Graphical representation of two proposed designs from Workshop Three, prepared as mirror data.

Participants discussed both designs, identifying appealing elements and alignment with the school's needs. The possibility of combining or narrowing them down to a single proposed design was also discussed. Both designs incorporated the school's wish to utilise the 8-week rotating block to engage second and third year students in computing. The discussions focused on the curriculum for each year group.

To shape the subsequent discussions and consider valuable contributions, the individuals who had gathered information since workshop three, presented their findings. Lecturer 3 shared a detailed showcase of an online cybersecurity platform aimed at educating younger people about computer science through engaging and interactive challenges (Figure 5.33). Lecturer 3 suggested considering the initiative's potential integration into the design and offered to reach out to the company to explore collaboration and availability.

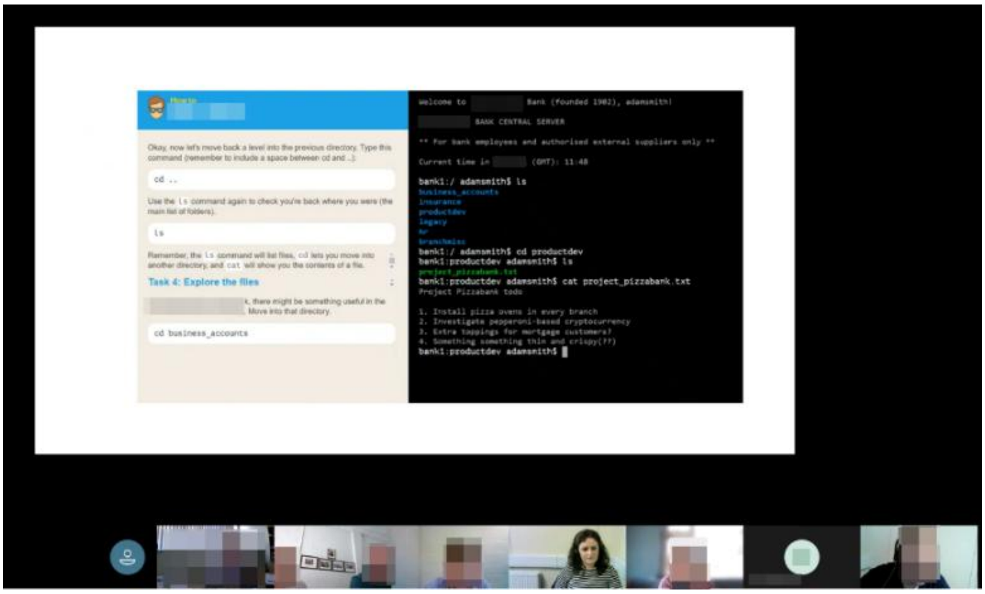


Figure 5.33: Lecturer 3 demonstrating potential resource to be integrated into design

A group discussion ensued to gather viewpoints on the online cybersecurity platform and its integration possibilities. STEM teachers expressed interest in its manageable challenges, which could be easily integrated into classroom activities. The Head of Department highlighted the resource's inclusivity and alignment with the female students' preferences, who he believes are more interested in creative computing. Undergraduate students expressed enthusiasm for its engaging and fun nature.

> "*the materials that are available are really good… I think that it would intrigue more students to do it just because it's fun to do*" – Undergraduate student 2, W4

Concerns were raised about potential confusion and hindrance to learning if students engaged in multiple challenges simultaneously. Lecturer 1 inquired if the resource provided additional teaching materials, such as lesson plans or worksheets, to enhance the learning experience and assist in fulfilling the schools 40 minute classes. Participants proposed incorporating the challenges from the online cybersecurity platform into the eight week rotating block or using it as a foundational component before starting a project. Schoolteacher 4 informed the DIRWG about the recent replacement of the junior certificate with the Junior Cycle Profile of Achievement (JCPA), which shifts focus away from traditional grading and more towards student achievements. This was viewed as an opportunity for our outreach initiative to align with this approach, with Schoolteacher 4 highlighting the potential benefits of awarding certificates to students for completing activities, similar to the challenges on the online cyber platform.

> “*What would be brilliant at the end, is if we had like a SETU Carlow certificate in combination with Tullow community school, and if someone from your department could sign and stamp it, and we would stamp it… then that can go into their profile of achievement for their junior cycle”* – Schoolteacher 4, W4

Lecturer 5 suggested a requirement that students demonstrate teamwork or project management skills to receive certificates, addressing the cyber platforms lack of these skills.

> “*with the cyber school thing… it's kind of like you're isolated and you're looking at a video, or that's my impression. I'm not sure if there's some way of tweaking it, but you kind of lose the teamwork thing. So [schoolteacher 4], when you're talking about certificates, it could be not just a certificate of completion, but that you worked on a project together. That's more substantial than I did this online thing”* – Lecturer 5, W4

Lecturer 5 was also concerned that the online cyber platform may not give students a true understanding of computer science:

> *“… while some of those challenges were brilliant, the idea of having a Linux command line run through a web browser, you kind of lose track of yourself, and this is first years, second years, potentially… I know some of them will get it, but I still see here sometimes people don't get virtual machines… you say to do something on the machine, they'll do it on the host machine rather than the virtual machine… no matter how seamless the interface is”*
> – Lecturer 5, W4

In terms of concept development, this builds upon earlier discussions around wanting to give students a true sense of computer science, and would eventually contribute to the formation of a concept highlighted in Figure 5.1.

The importance of sustainability and broader impact beyond one school was emphasised.

> “*… what I like about it is the sustainability of it… you can run this yourself with little interaction from us… as well with the quality of the activities… we could have 10 of our lecturers working all year… and we wouldn't be able to come up with stuff as good as this*.”
> – Lecturer 3, W4

Discussions returned to apprehension towards the online cyber platform and its main focus on cybersecurity. Interest was expressed in obtaining information on the impact of the online cyber platform to increase participation in Computing:

> "*My feelings are that it's a… blinkered view of what Computing is, because it's only looking at stuff from a cyber perspective… a great way to introduce a whole load of technology and skills to students but most Computing isn't cyber"* – Lecturer 2, W4

Participants highlighted the importance of providing a meaningful and engaging experience for students in the collaboration between the school and the university.

> "*I think as an outreach initiative, we would probably want to be seen on a very regular annual basis, because otherwise, there's no real advantage, you're not creating an outreach initiative "* – Lecturer 2, W4

> "*for me… it's the experience between the school and the university and what we are doing. What are we uniquely adding? All the tools that we've talked about… are great but we want the students to experience it... it's not just the technical skills, it's the social skills… for me that's kind of true outreach… and maybe then that will attract females as well as getting students to stay involved in computing*" – Lecturer 5, W4

It was decided that further clarification on the concerns raised would be sought from the online cyber platform owners before determining its feasibility for integration, which would be revisited in a future workshop.

The participants discussed the project idea document (Figure 5.34), which included six projects designed to cater to the diverse interests of students across various computing domains with an emphasis on skill progression and creativity. The document was shared with STEM teachers who shared it with fifth-year students through an anonymous survey. However, the data from the survey had not yet been reviewed at the time of the discussion.

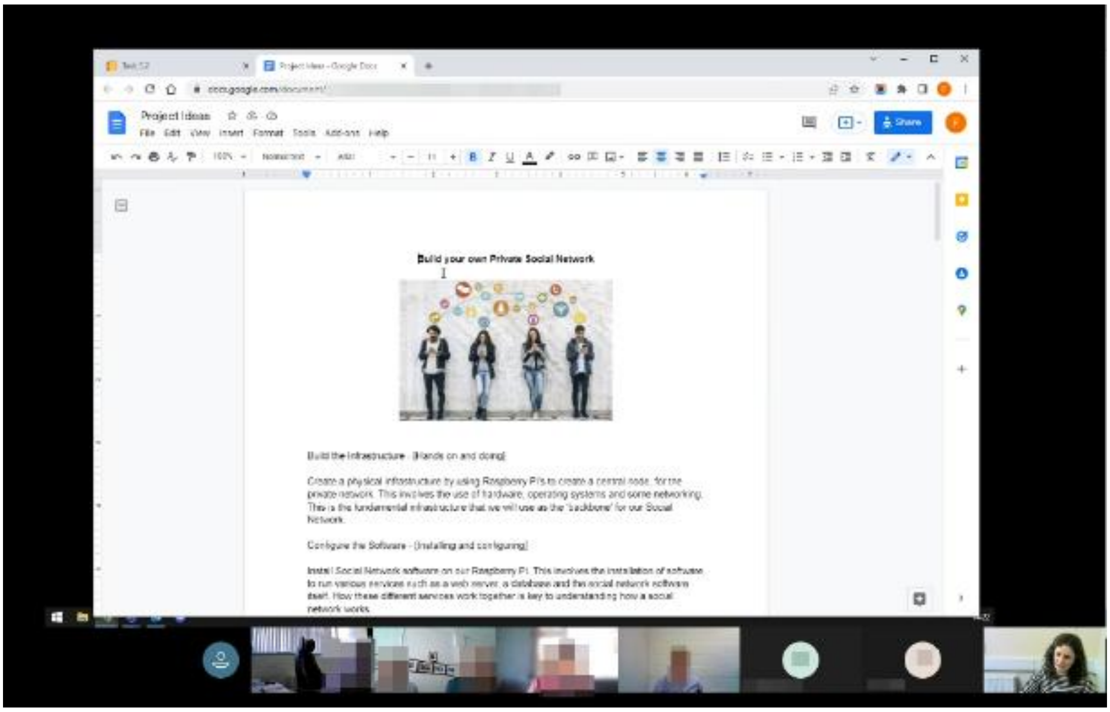


Figure 5.34: The group discussing the project idea document on Teams

Contributors of project ideas had the chance to explain their thinking and answer questions about their proposals, while schoolteachers provided feedback on the presented projects. Recognising the importance of student input, it was agreed to seek feedback from students on the projects and revisit in the next workshop to discuss incorporating existing or new projects into our design.

A schoolteacher highlighted how one project idea was structured over three stages, each focusing on a core area and building upon the previous stage, leading to a final comprehensive project. This was seen as an opportunity to develop a progressive curriculum plan.

> *"I actually see a lovely progression there… how it's pulling from each little area… What we could do in 1st year is do some of the cyber challenges… how to create the vector graphics… awareness of what font looks like… we're going to integrate it later on as your own website… and… by the time they get to third year, they're going to incorporate all that into their own project… but they can't do that either without having a knowledge of the physical components to put together the Raspberry Pi, so you're going to need… the analytical data, the installing… the encrypting of it… If we structure it a bit better… there's a good bit of everything there."* – Schoolteacher 4, W4

> "*… if we come up with a progressive plan where they're getting a look at cyber, Linux, hardware, creativity with social media and design… they get a round view and through those experiences, students would get a feel for whether or not they like hardware and building things or if they like doing something creative*" – Lecturer 6, W4

The DIRWG asked schoolteachers if there were curriculum or education guidelines that needed to be followed or if there was flexibility to adapt the curriculum based on guidelines or preferences. It was proposed that the online cyber platform's resources may be suitable for first year students only with the need to provide higher year students with a more accurate understanding of computer science.

The fifth year mentorship programme was further discussed and a high-level plan for the progressive curriculum began to take shape, with considerations for the curriculum for junior cycle years. Discussions and debates were held to determine the curriculum for each of the three years, incorporating inclusive topics to suit all student profiles. Suggestions for the curriculum included HTML, CSS, design, vector graphics, security, Linux, and hands-on projects involving Raspberry Pi's. A brief description of the content for each of the junior years was documented on Notion, as shown in Figure 5.35.

Indicative Progressive Curriculum

OUR GOAL: Design a curriculum that progresses nicely from 1st year to 3rd year using 8-week rotating block. Each year building on the next (stepping stones) with the goal of integrating all areas into the project in 3rd year:

REMINDER OF THE JUNIOR CYCLE - **Profile of Achievement document** (taking the emphasis off grades and more on extracurricular / academic stuff) - students could receive a certificate of achievement stamped by and for activities they've completed or participated in.

1st years: (MS Office Suite, HTML & CSS, Design, Vector Graphics)

- could do design vector graphic stuff and use some of the cyber activities (https://cyber where they look at making design decisions.
- very self-guided and structured that a teacher with basic knowledge could deliver. If students complete all activities, get signed off by and to provide certificate of completion → which they can add to their profile of achievement for junior cycle.
- inform students that the graphics they design, and their understanding of what fonts look, aspects of design and presentation etc, they will build on this in 2nd year and then integrate everything into third year project where they build their own social media type website.
- Possibility for certificates of achievement for junior cycle folder

2nd years: (Security, Linux)

- 8 weeks
- progress on from 1st year to learn a bit about security and Linux (cyber to get familiar with basic Linux commands (Linux through web browser). How to protect a website from being hacked and encryption etc.. (l and How to essons),
- Can inform students here that the skills they pick up on here in security and choosing secure password and Linux commands etc and last years stuff, they will integrate this into third year project.
- Possibility for certificates of achievement for junior cycle folder

3rd years: (Hardware, Networking, Operating Systems, Installing and Configuring Software)

- 8 weeks
- **Visit from** **lecturers to** to introduce project and plan for them to come to us in 8 weeks to present their final project and receive a certificate of completion from .
- do the **project** (e.g., build your own social media platform from Project Ideas) or design some kind of website and host it on a raspberry pi that they have also setup and configured to act as a web server.
- building on knowledge and skills from previous two years (designing graphics, HTML & CSS, Linux commands) → hardware and physical computing using Raspberry Pi's (Linux directly on hardware).
- **Visit from** **students to** (visit would need to be before February before they choose 5th year subjects - but then all groups won't be finished project) to present their projects as well as other activities planned on campus that day like tour of campus facilities, talks from UG students etc, and to be presented with certificate of completion.

5th years:

- During 10-week practical project - UG students to visit 5th years in - Nigel in support of funding mini bus

Figure 5.35: Overview of progressive curriculum plan (Notion wiki, Task 4A)

The DIRWG offered their assistance in creating lesson plans or designing the curriculum in the future. The STEM teachers reiterated that including the college's name over the lessons would motivate students. The participants were requested to review the proposed curriculum before the next workshop and to provide their reflections at the next workshop.

Two key points were raised around needing more experienced teachers for the third year curriculum in comparison to the first year computing subject, and also if we were planning to implement this design in the forthcoming September that the third year students would not have completed the curriculum planned for first and second year.

The discussion then shifted to the site visits proposed in design one. It was agreed that the site visits would be exclusive to third year students working on projects, as including other years would be difficult to manage. The Head of Department confirmed that certificates could be presented to students upon completing their projects during the visit to campus. The timing of the site visit to campus was discussed with schoolteacher 1 adding:

"… they choose their subjects for 5th year in February, so by coming over to campus after that, might defeat the purpose a little bit. Whereas if it's fresh, exciting and they've seen the college… they may want to choose Computer Science for 5th year"

– Schoolteacher 1, W4

It was noted that scheduling it before Christmas would pose a challenge as some groups might not have completed their 8 week projects by then. The STEM teachers agreed to investigate the 8 week rotation block further for the next workshop.

Lecturer 3 emphasised a couple of important points. Firstly, booking school students into the campus would realistically be feasible a maximum of twice a year. This highlighted the need to design a sustainable and pragmatic solution that could be easily implemented to run. Additionally, Lecturer 3 acknowledged that while the DIRWG would provide assistance, it was important to be realistic with expectations, considering everyone's busy schedules.

In terms of concept development, the comment by Lecturer 3 was the first instance where *sustainability* was mentioned and was later revisited by participants during discussions and debate over the importance of designing an initiative that was sustainable. This was the initial formation of a concept which would later be titled *sustainable collaboration*, shown in Figure 5.1.

Plans were made for workshop five, scheduled for four weeks later. Assignments were given to the STEM teachers to explore the 8-week rotating block, and for Lecturer 3 to contact the cyber company for further information. Additionally, feedback from student survey would be reviewed and the possibility of gathering information on past students of the school who have pursued computing at third level would be sought. In particular those who are existing computing students in the department, with the aim of inviting them to mentor fifth year students in their own school, considering their background and proximity to the school.

5.3.5.3 The implications for the design

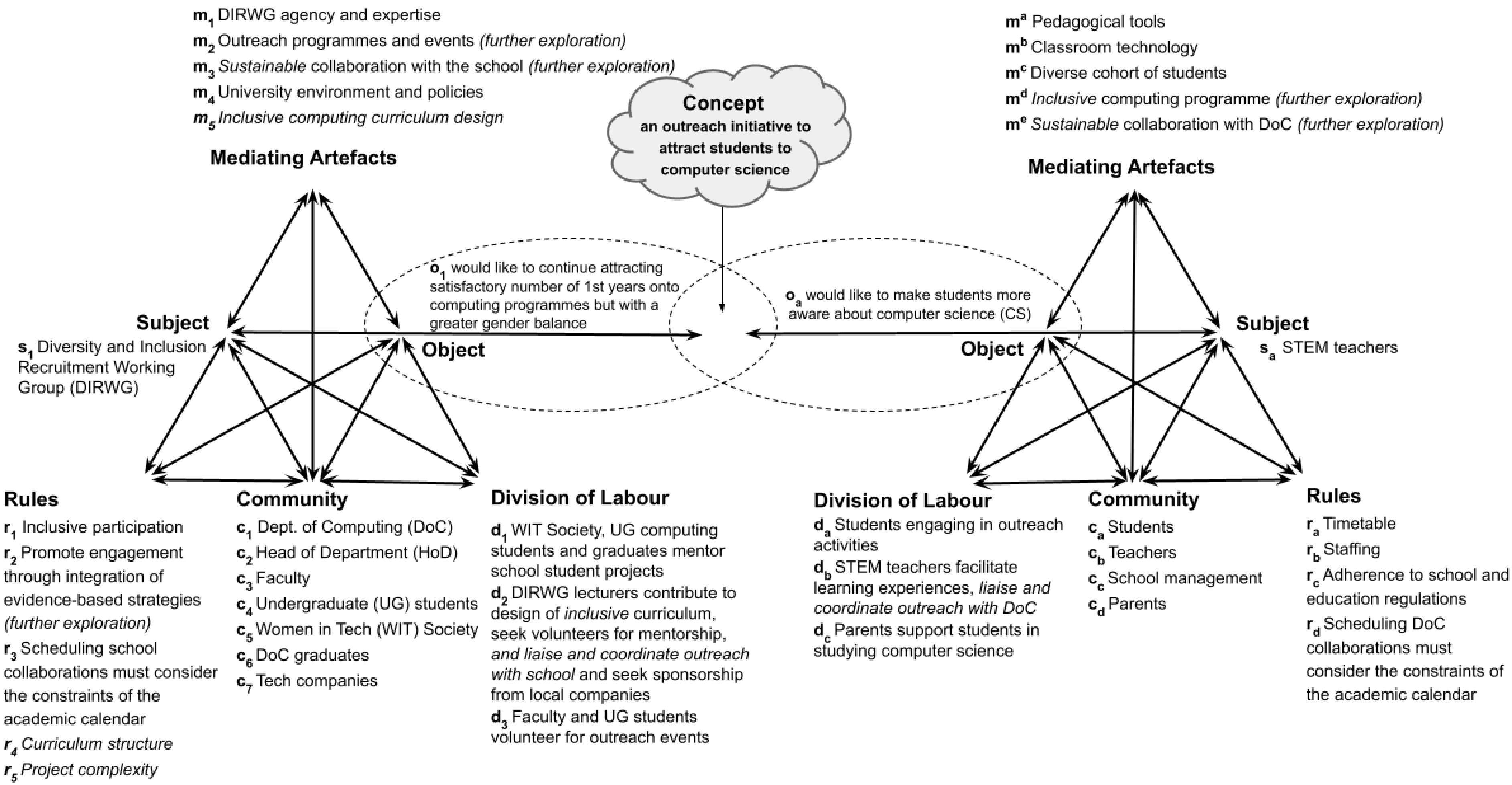


Figure 5.36: Design implications arising from workshop four

Figure 5.36 illustrates the design implications resulting from workshop four in italicised text. These implications arose when considering design implications and current practices and their rationale will now be explained.

When participants were considering the design in this workshop:

- they agreed that DIRWG lecturers (d_2) and STEM teachers (d_b) would liaise and coordinate outreach activities such as those included in design implications - m_2, m_3, m_d and m_e.
- they explored design implication m_2 again. Further suggestions about the mentorship programme were to investigate, if possible, to get information on past school students who are pursuing computing in the university, to return to old school as mentor/role model.
- they explored design implications m_3 and m_e again. It was decided to include certificates of achievement in the site visit to the university campus which acknowledges student completion of work involving teamwork. Certificates to be signed and stamped by both partners. Participants also decided that the collaborations designed needed to be a sustainable and pragmatic whereby they could be run for many years and that they were realistic in terms of expectations around resources and people's availability.
- they explored design implication m_d further. It was decided that the design of 8-week taster courses in computing that would consist of a progressive curriculum plan (r_4) that promotes engagement (r_2). This would start in 1st year with a planned curriculum that was designed to be inclusive to all (m_5) and that had progression each year up to third year. It was decided that the project (r_5) would be introduced to third year students at the start of their 8-week computing course and the design of this project would incorporate school student feedback on project topics and would be created by the DIRWG lecturers (d_2).

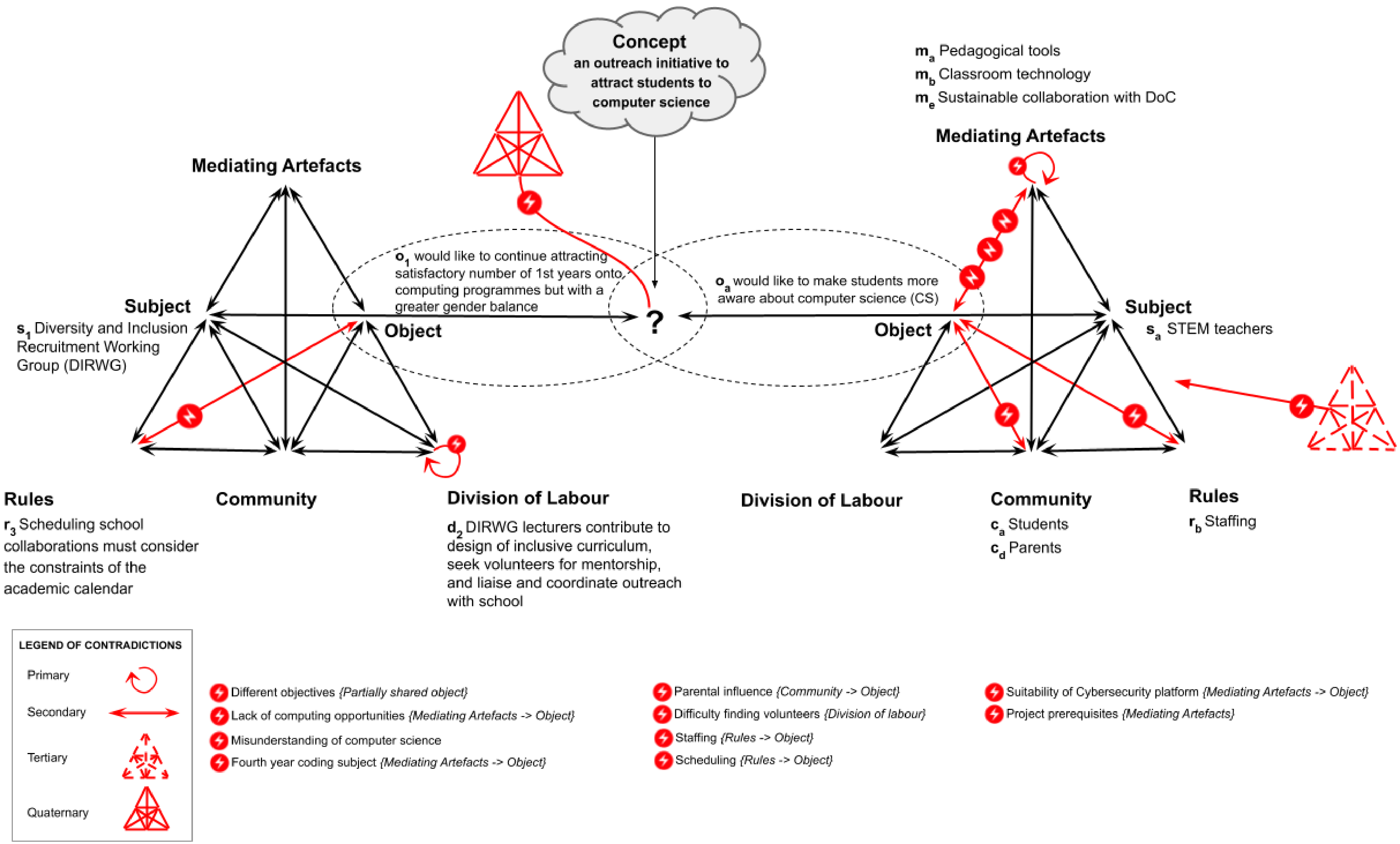


Figure 5.37: Contradictions at this stage of the design process, considering design implications and current practices

Four new contradictions were identified at this stage of the design process and no previous contradictions were resolved. The new contradictions are included in Figure 5.37. Participants hope to overcome all contradictions during the design process so that they do not exist in the new activity system. The contradictions identified in workshop four are described as follows:

- *Suitability of cybersecurity platform.* This secondary contradiction occurs between mediating artefacts m_a (pedagogical tools – the proposed online cybersecurity platform) and the object o_a. While the platform was initially considered as a tool to introduce computing concepts, participants expressed concern that it might offer a narrow and overly specialised view of the field , omit collaborative/teamwork elements, and limit opportunities for direct engagement with the Department of Computing (DoC). These issues create a misalignment
- *Staffing*. This secondary contradiction occurs between rule r_b (staffing) and object o_a. The proposed design requires specialist computing teachers for the 2nd and 3rd year curriculum, but the school currently lacks sufficient staff with the necessary expertise. This staffing shortfall directly conflicts with the object by constraining the delivery capacity of the initiative and limiting its sustainability.
- *Scheduling*. This secondary contradiction occurs between rule r_3 (school-university collaborations must align with the academic calendar) and object o_1. Participants agreed that site visits to the university would be most impactful before February, when subject selection decisions are made. However, existing schedules and term structures make this difficult to arrange, creating a temporal misalignment that reduces the initiative's potential influence on student choice.
- *Project prerequisites:* This primary contradiction occurs within the mediating artefacts element of the school's computer science education activity system. The proposed third-year project is designed to build on skills and knowledge acquired in the first and second years of the progressive curriculum. In the first year of implementation, however, the current third-year students will not have completed these earlier stages, leaving them underprepared to engage fully with the project. This gap between intended tool use and learner preparedness creates a tension that could limit the project's effectiveness and require interim adaptation.

5.3.5.4 *Reflective research diary notes on workshop*

Immediately following workshop four, I jotted down my opinion on the workshop in my research diary, a sample of which is shown in Figure 5.38. I was extremely satisfied with how my visual depictions of the two proposed designs were received by participants and they worked well for kick starting discussions. My strategic aim with this workshop and its only task, task 4A, was to let the conversation flow between the group as much as possible within the timeframe available. I think this openness led to some innovative suggestions and decisions being made about the design.

Reflecting further, I believe the workshop successfully stimulated the expansive learning actions of modelling and examination. Modelling involves experimenting with new ideas, and the participants actively explored both designs, suggesting modifications and new elements that could improve the initiative. Examination, on the other hand, is about critically analysing these ideas to assess their practicality and alignment with our goals. This was evident when participants discussed the feasibility of incorporating external resources, like the online cybersecurity platform, and debated its impact on the students' understanding of computing.

Upon the workshop's conclusion, it became evident that establishing a well-defined objective for the co-designed outreach initiative would greatly aid participants in assessing whether the proposed design aligns with the needs of all stakeholders. This realisation sparked the idea to introduce a new task into my design for workshop five, aimed at accomplishing this goal.

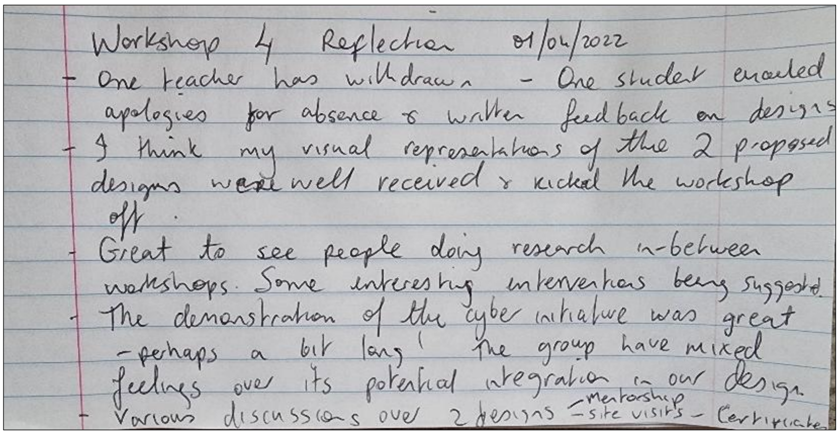

Workshop 4 Reflection 01/04/2022
- One teacher has withdrawn - One student emailed apologies for absence & written feedback on designs
- I think my visual representations of the 2 proposed designs were well received & kicked the workshop off.
- Great to see people doing research in-between workshops. Some interesting interventions being suggested.
- The demonstration of the cyber initiative was great - perhaps a bit long! The group have mixed feelings over its potential integration in our design.
- Various discussions over 2 designs - Mentorship - site visits - Certificate

Figure 5.38: Sample of reflective research diary notes for workshop four

5.3.6 Workshop five

5.3.6.1 The design of the workshop

My intention with my design for workshop five, as set out in Table 5.5, was modelling, examination and reflection. To achieve this, I included two tasks. Task 5A would involve participants describing the core object of our activity, which meant to identify the main objectives of this initiative. Task 5B aimed to move things forward by having participants examine and reflect on the proposed design by making low-level decisions on aspects such as delivery method, duration, coursework, lesson plans and any other design details that needed planning and agreement. The outcome of task 5A would facilitate these decisions by evaluating if the answers align with the core objective.

Table 5.5: Workshop five design

	WORKSHOP FIVE 29.04.2022			
	Expansive learning action: Modelling, Examination, Reflection			
	First-stimuli	**Second-stimuli**	**Mirror-data**	**Social organisation**
TASK 5A	What is the core object of our activity?	Object documented on Notion and made available to serve as mirror-data.	Visual illustration of proposed design	Group (8)
TASK 5B	What low-level decisions do we need to make to progress the design?	Table of detailed questions with criteria to align with core objective.	Outcome of Task 5A and access to full workspace.	Group
	Documentation, discussion and Recording	Use Notion workspace to record discussions and ideas. Use MS Teams to host and record workshop.		

5.3.6.2 The progress of the workshop

The fifth workshop, attended by 8 participants on Teams (Figure 5.39), began with a recap on the previous workshop and an update from individual participants who had carried out research on items discussed in the previous workshop that would assist the progress made in this workshop.

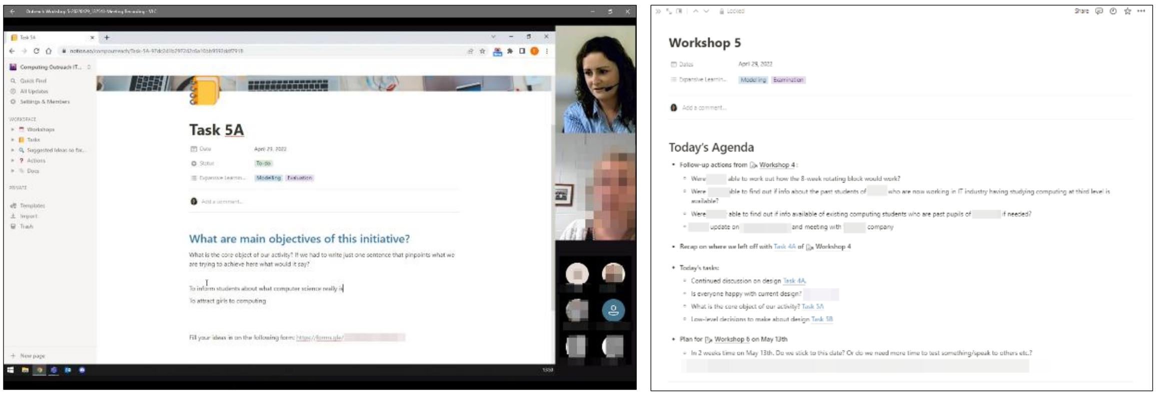


Figure 5.39: Workshop Five-group working on task 5A (left), session agenda on Notion (right)

Participants provided individual updates to the group on the information they found. For instance, lecturer 3 and lecturer 6 had a meeting with the owners of the online cybersecurity platform in the UK, about the possibility of incorporating their resources into the inclusive computing curriculum. It was determined that they were willing to facilitate us to use their online challenges in the school and other schools in Ireland. Consequently, the group decided to keep these activities provisionally included in the curriculum as discussed in the previous workshop. Participants were given the chance to reflect on the progressive curriculum, and all agreed that the syllabus would remain as it is, with no modifications requested.

Participants were then tasked with narrowing down the main objectives of this initiative into a statement that encapsulates the main goal they want to achieve. The Notion page for Task 5A was displayed (Figure 5.39) for participants to access and type into while forming a statement collectively. Participants considered various wording and keywords, with some playing with words in Teams chat feature also, for reaching a consensus on the objective. These mainly revolved around wanting to develop an engaging and sustainable computer science programme that will attract all students, in particular girls, to computing and how they wanted designing a curriculum to achieve this goal. Two lecturers responded with similar objectives "*to attract girls to computing*" (Lecturer 1) and "*to bring women to computing*" (Lecturer 3).

The STEM teachers were asked if that was their main objective, to which the primary ICT teacher confirmed it was not, but it was still a priority:

> "*That wouldn't be our main one, but it's possibly second. Our main objective is to inform all students of what computer science is before they take the subject… giving them a view of all the wonderful things that can happen in computer science*"

– Schoolteacher 1, W5

The researcher-interventionist recalled conversations from previous workshops:

> "*we need to be true to students about what computer science really is. And not give them any false information about it, and that they know what they're getting into when they come to study it at third level*" – Lecturer 6, W5

In terms of concept development, these comments by schoolteacher 1 and lecturer 6 were further instances where the subjects wanted to dispel misconceptions and give students a true sense of computer science. This would eventually contribute to the formation of the concept titled *show the varied and true nature of computer science*, as illustrated in Figure 5.1.

The DIRWG members reiterated that the objective of their activity was to increase female participation within the existing satisfactory number of first year enrolments. It was acknowledged that as participants are from two different institutions, that we had two different objectives, and the goal was to try to come up with an objective that encapsulates those as one.

> "*Yeah, I think you can meet the two of those objectives at the same time, like you can inform everybody of what exactly computer science is about, and then… have activities that attract both boys and girls… then maybe we kind of play special emphasis here on the attracting girls part, but still the boys are taking care of as well at the same time… It's, yeah, I think the two of them can be achieved at the same time*." – Lecturer 3, W5

Participants questioned the purpose of joining individual objectives into one statement to which my response provided the reason that it would describe the outreach programme co-designed between partners at a high-level, so that when we move on to making low-level decisions about it that each aspect can be compared against our main objective.

Lecturer 1 brought up the university's forthcoming transition to a semesterised system and expressed concerns about its potential impact on the recruitment for the department's computing courses.

> "*I was just going to say that… we don't know what's going to happen with the university… we've been fine holding our numbers so far, but that's not to say that's going to happen in the future as well. So… we have to continually keep attracting all students, not just females… so I kind of think like what [lecturer 3] was saying… both of them can be as one really, just to get to keep the word out there that Computing is still… a super time to study*

it and to put maybe an extra emphasis… that there's lots of opportunities for girls in this "

– Lecturer 1, W5

Following multiple suggestions of wording and key phrases that participants felt should be included, lecturer 4 summarised all participant suggestions into one statement as follows:

"To create a sustainable collaboration between SETU (Carlow Campus) and Tullow Community School to enable students to understand the varied and true nature of computer science through an inclusive curriculum. This should facilitate a more diverse cohort of students to engage with computing in 2nd and 3rd level education."

– Lecturer 4, W5

All participants agreed that this statement accurately described the core objective of what we were trying to achieve, and this was now decided.

Task 5B required participants to contemplate and make detailed decisions to fine-tune the design preparing it for implementation. However, its implementation is not focused on in this thesis. Ahead of the workshop, a table of questions was prepared on Notion for participants consideration for each year of the junior cycle and fifth year mentorship programme (Figure 5.40). The core objective formed in task 5A was pasted at the top of the page as a reminder (mirror-data) of what it is we are trying to achieve. Columns were added to the table, using key words from the core objective as a criteria, so that for each question we could collectively a) note the answer b) analyse its sustainability c) evaluate if it was inclusive, showing the varied and true nature of CS d) make decisions that would facilitate a diverse student cohort and e) add who would be responsible for that aspect. For instance, one question asked *what will the curriculum include in 2nd year and what resources are needed?* The group collectively decided that it would be an 8-week curriculum focused on data, networking, Linux, security and two specific challenges identified from the online cyber platform. This was noted in the column titled answer. The group considered this as sustainable as they felt when the curriculum is written once, the majority can be re-used in the future. They also considered the curriculum as inclusive, enabling students to understand the varied and true nature of CS, with careful consideration given to the pedagogical tools to be used to facilitate a diverse student cohort (i.e. mixture of hands-on activities, teamwork, teacher support). The group decided who would be responsible for overseeing the curriculum and those people were noted in the final column of the table. The same process was completed for each question in the table and more questions were also added during this task.

Tasks / Task 5B Locked　　　　Edited just now　Share

"To create a sustainable collaboration between and to enable students to understand the varied and true nature of computer science through an inclusive curriculum. This should facilitate a more diverse cohort of students to engage with computing in 2nd and 3rd level education."

Table

Decisions we need to make...

Year	Item	Answer	Sustainable?	Varied and true nature of CS - inclusive?	Facilitate diverse student?	Who is responsible?
1st	What will the 1st year curriculum include?	To use the existing 1st year curriculum (Microsoft Office Suite, HTML, CSS, Design Vector Graphics) which will run for the full year.	Yes - done once	Yes	Yes	STEM teachers
1st	What resources are needed to deliver this subject?	The aim is for any teacher with basic knowledge to be able to deliver this subject.		N/A		STEM teachers
1st	Has this initiative added anything new to the 1st year computing subject?	Yes - Students can complete some of the activities (e.g.) and receive a certificate of completion? https://cyber	Yes - done once		Yes	DIRWG
1st 2nd 3rd	Who will organise certificates of completion?	Specific members of DIRWG and STEM Teachers	Yes - once per year		Yes	FR DIRWG STEM teachers
2nd	What will the curriculum include and what resources needed?	2nd year 8-week curriculum to focus on data, networking, linux, security and a couple of cyberskillslessons activities.	Yes - done once	Yes	Yes	STEM teachers DIRWG
2nd	Who will write 8 week curriculum as per agreed design, with college name over it?	DIRWG to assist with design of 8-week material and coursework	Yes - done once			DIRWG FR
2nd	When will new computing subject be introduced?	September 2022	Yes - done once			
3rd	What will the project(s) be?	Feedback from students shows that Building a Social Media Platform was the project students were most interested in.	Yes - done once		Yes	DIRWG FR
3rd	Who will write the project brief and any complementary material needed?	DIRWG members - and FR	Yes - done once		Yes	DIRWG FR
3rd	Will additional experienced teachers to required to teach the 3rd year curriculum?	Yes. have started making initial assessment of staff allocations for new and existing computing subjects.				STEM teachers
3rd	When will new computing subject be introduced	For September 2022, the 3rd year subject will be introduced but those students will do the same as the 2nd				STEM teachers

Figure 5.40: Task 5B: Table of participant responses aligned with the core objective

Discussions around facilitating a diverse student cohort included the need to build an environment that didn't segregate girls and that felt supportive. Participants felt that with each aspect of the design, we need to be more mindful about integrating evidence-based strategies that promote engagement and inclusive teaching and learning, especially for females. Strategies from specific research papers were mentioned including one titled *Reflecting on the Impact of a Course on Inclusive Strategies for Teaching Computer Science* (Joshi and Jain, 2018).

The group showed an awareness of challenges that females face in class, with participants recalling conversations from previous workshops such as females being too shy to ask questions, not very many females in the classroom, sometimes females with less prior experience in computing as the males and if a teacher allows certain students to dominate the class.

Plans were made for workshop six, originally scheduled for two weeks' time but it was decided at the end of workshop five that additional time was needed to reflect on the design and to follow up on aspects requiring more information. For example, the group felt it would be beneficial to get school students opinion on the titles of the newly designed computing subjects and what would appeal to them. So between workshop five and six, along with the main ICT teacher, I designed an anonymous survey which was shared with students with suggestions of computing subject titles and options for students to suggest their own titles. The sixth workshop was therefore rescheduled for one month later.

5.3.6.3 The implications for the design

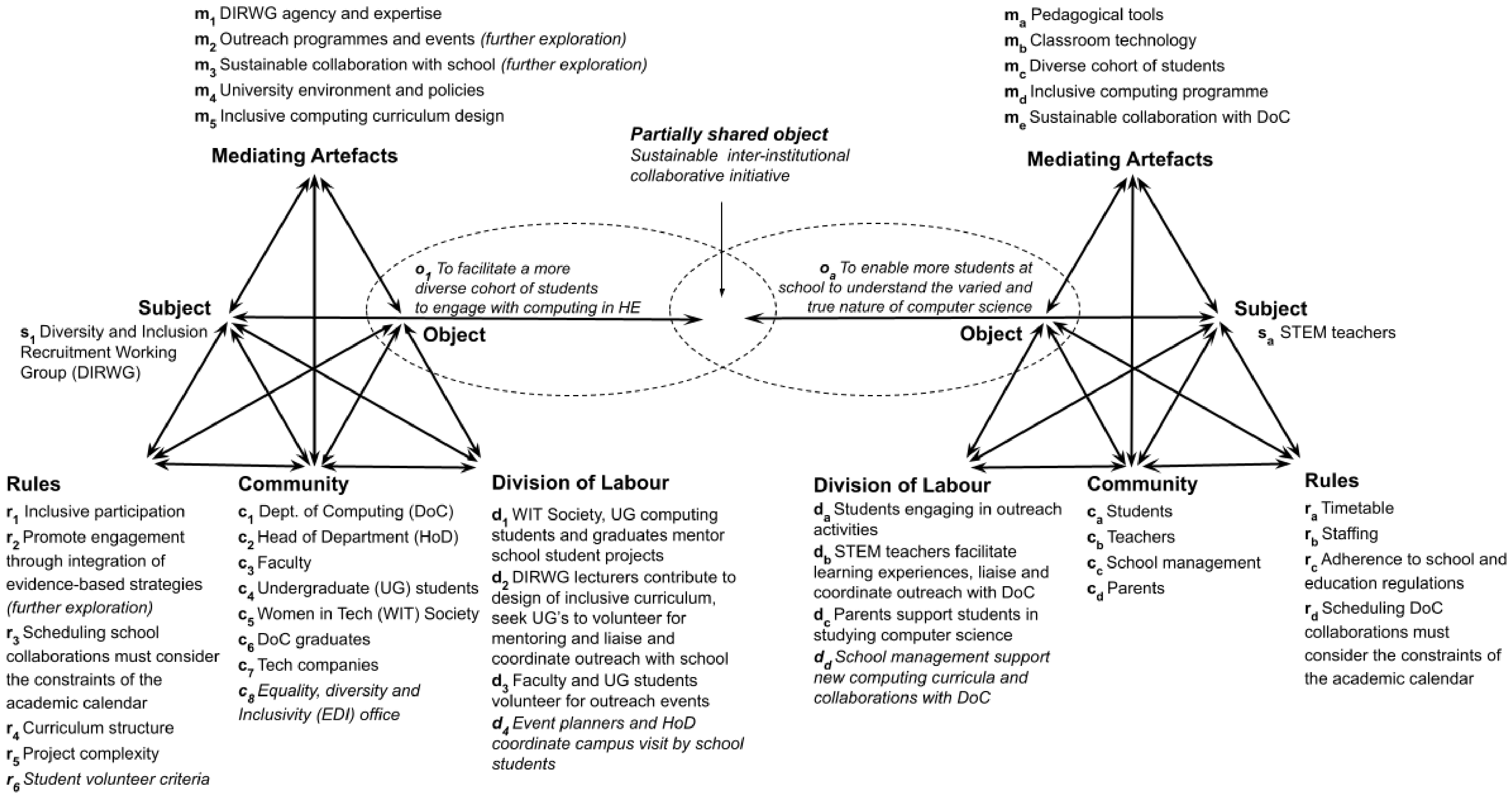


Figure 5.41: Design implications arising from workshop five

Figure 5.41 illustrates the design implications arising from workshop five in italicised text. These implications arose when considering design implications and current practices and their rationale will now be explained.

When participants were considering the design in this workshop:

- they explored their core object, a partially shared object, and agreed on a statement that collectively they feel describes their goals.
- they explored design implication o_1 again. The object of the Computing Department's bespoke outreach activity system was revised based on the formation of the core object, to facilitate a more diverse cohort of students to engage with computing in HE.
- they explored design implication o_a again. The object of the school's computer science education activity system was revised based on the formation of the core object, to enable more students at school to understand the varied and true nature of computer science.
- they explored design implication m_5 again. Further refinements were made around the DIRWG members writing a project idea document (d_2, r_5) to include the creation of an inclusive computing curriculum (m_d).
- they explored design implication m_a again. Further decisions were made around the pedagogical tools that STEM teachers would use to achieve their object. Including evidence-based strategies (r_2) to attract and support minority groups such as females.
- they explored design implication d_d and agreed that school management would need to support the new computing curricula and collaborations with the DoC.
- they explored design implication m_2 again. Further refinements were added to the mentorship programme.
- they explored design implication m_3 and m_e again. Further refinements were added to the site visits.

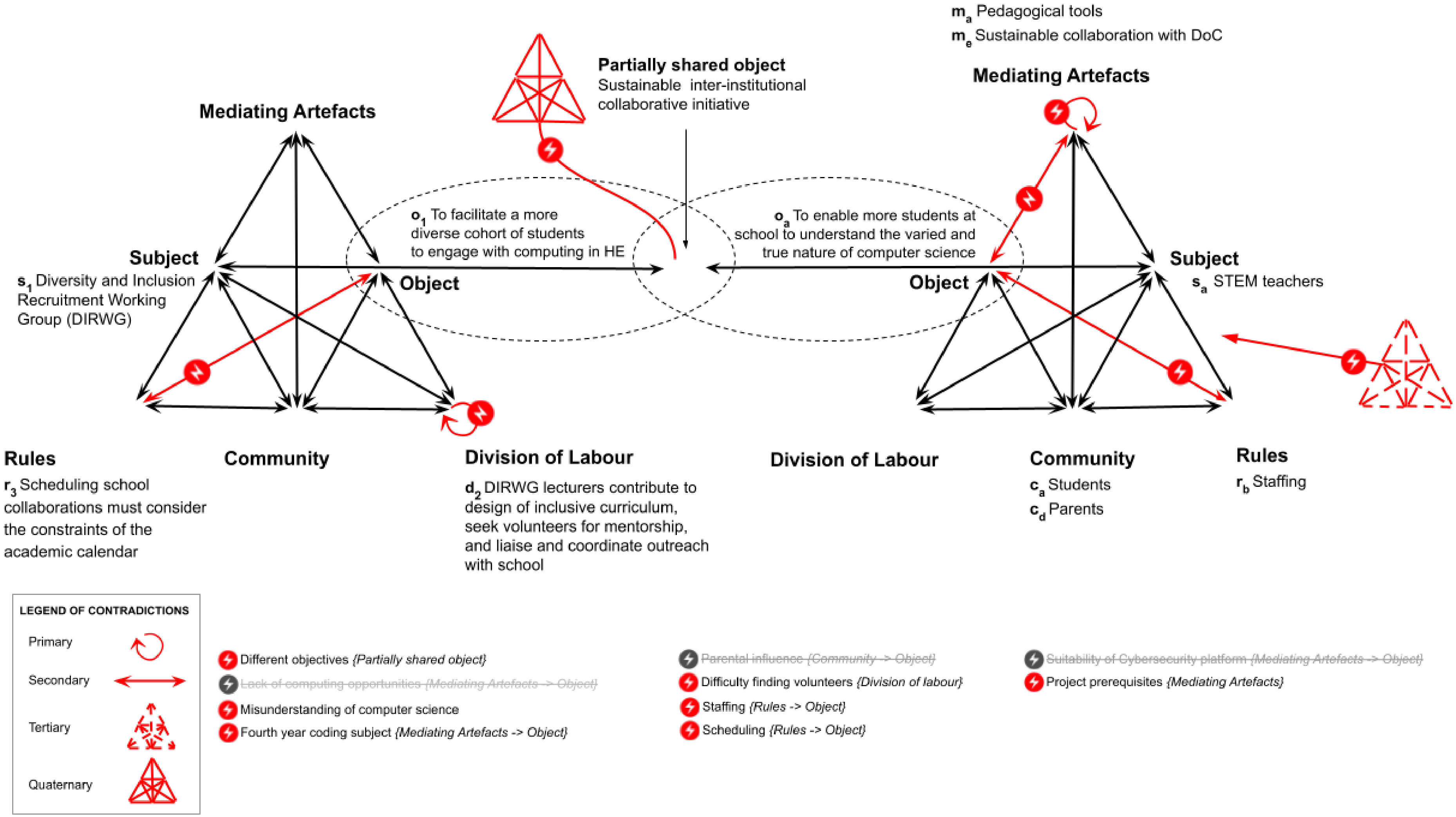


Figure 5.42: Contradictions (existing and overcome) at this stage of the design process, considering design implications and current practices

Three contradictions were resolved at this stage of the design process, and no new contradictions were identified. The contradictions that were overcome during workshop five are highlighted in Figure 5.42 and they are described as follows:

- *Lack of computing opportunities.* This was a secondary contradiction identified in workshop one, occurring between mediating artefacts m_a (pedagogical tools) and object o_a. In the existing system, the absence of computing in the second and third years limited sustained engagement. Participants felt this contradiction was resolved in the proposed design by introducing new computing curriculum elements into both second and third year, thereby creating continuous opportunities for students to develop skills and interest in the subject.
- *Suitability of cybersecurity platform.* This was a secondary contradiction identified in workshop four, occurring between mediating artefacts m_b and object o_a. Initially, participants were concerned the platform would narrow students' perceptions of the field. This contradiction was resolved by embedding the platform's resources in the first and second year curriculum, where they could add value, while excluding them from the third year curriculum, where the focus would be broader and more authentic computing experiences.
- *Parental influence*. This was a secondary contradiction identified in workshop two between the community (c_d- parents) and object (o_a) elements of the schools computer science education activity system. Previously, parents were perceived to discourage students from choosing the LCCS subject, often prioritising subjects believed to yield higher grades. Participants felt this contradiction was resolved through the proposed second and third year computing curriculum, which would give parents earlier and more tangible evidence of their children's achievements in computing, thereby reducing the likelihood of discouragement.

5.3.6.4 Reflective research diary notes on workshop

Immediately following workshop five, I reflected on the workshop in my research diary, a sample of which is shown in Figure 5.43. In this, I captured my thoughts on how the workshop progressed. I found it to be highly productive, characterised by collaborative decision-making and active participation. Task 5A which centred around formulating a core objective, was particularly successful, with participants engaging deeply in discussion and collectively agreeing on a clear, unified statement. The inclusion of this task streamlined the subsequent activities in the workshop beyond my expectations. Additionally, I felt that the first-stimulus and mirror-data worked effectively in provoking thoughtful discussions.

Reflecting on the expansive learning actions, I believe this workshop successfully stimulated modelling, examination, and reflection. Modelling refers to the creation of new ideas and solutions, and this was evident in how participants explored different formulations of the core objective, engaging with diverse perspectives and merging individual goals into one cohesive objective. Examination, the critical analysis of these ideas, was demonstrated in the group's careful evaluation of the curriculum design, ensuring alignment with the newly formulated core objective. They assessed whether the proposed outreach initiative would truly serve the goal of increasing engagement in computer science, particularly for underrepresented groups like girls. Finally, reflection was evident as participants revisited and reconsidered prior decisions, discussing the long-term sustainability and inclusivity of the proposed design, particularly in light of the challenges previously identified in earlier workshops. The contributions from all participants indicated a deep level of reflection on how each aspect of the design could be improved and aligned with the group's overarching goals. Overall, the workshop successfully achieved its aims, both in terms of content and process.

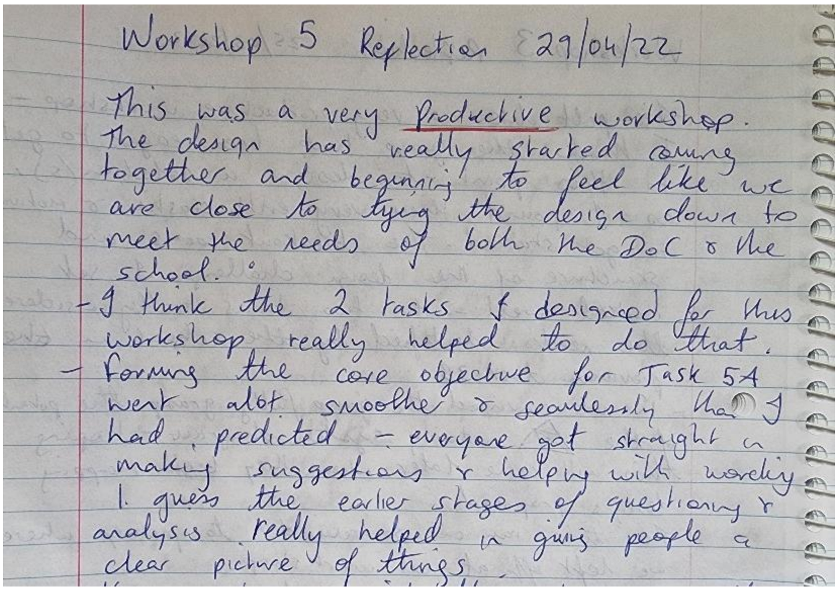

Workshop 5 Reflection 29/04/22
This was a very productive workshop. The design has really started coming together and beginning to feel like we are close to tying the design down to meet the needs of both the DoC & the school.
- I think the 2 tasks I designed for this workshop really helped to do that.
- Forming the core objective for Task 5A went alot smoother & seamlessly than I had predicted - everyone got straight in making suggestions & helping with wording. I guess the earlier stages of questioning & analysis really helped in giving people a clear picture of things.

Figure 5.43: Sample of reflective research diary notes for workshop five

5.3.7 Workshop six

5.3.7.1 The design of the workshop

My intention with my design for workshop six, as set out in Table 5.7, was reflection. I sought to make that work by including two tasks. Task 6A provided a reminder of the latest proposed design as agreed by participants and updates on any in-between workshop activities carried out by participants. With task 6B, I sought to understand how participants perceived their newly designed outreach initiative as meeting the needs analysed by the stakeholders involved.

Table 5.6: Workshop six design

	WORKSHOP SIX 21.06.2022			
	Expansive learning action: Reflection			
	First-stimuli	**Second-stimuli**	**Mirror-data**	**Social organisation**
TASK 6A	Recap on proposed design Update on progress since last workshop	Feedback and comments recorded	Visual material illustrating proposed design and updates on latest progress	Group (6)
TASK 6B	How well do you think this outreach initiative we've designed meets the original needs identified by the school and the university?	Answers recorded on Teams	Task 6A diagrams and whole Notion workspace.	Addressed individually
	Documentation, discussion and Recording	Use Notion workspace to record discussions and ideas. Use MS Teams to host and record workshop.		

5.3.7.2 The progress of the workshop

Workshop six (Figure 5.44) was planned for May 27th, however unforeseen circumstances forced us to reschedule it to June 21st. Unfortunately, this new date coincided with the summer break when teachers, lecturers, and students were away, leading to a lower attendance. As a result, just 6 participants were able to attend.

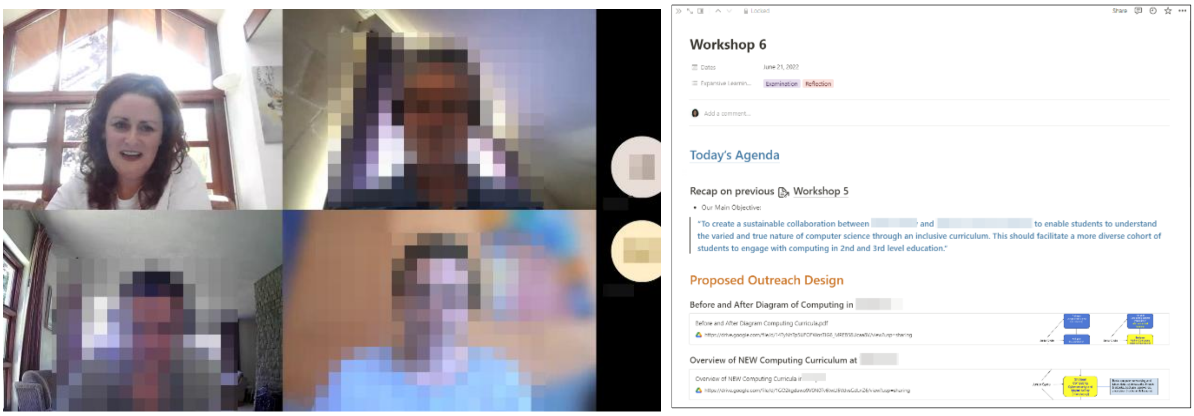


Figure 5.44: Workshop six – a group discussion (left) and workshop agenda (right)

For task 6A, the conversations revolved around finalising plans for introducing the new design in the school. We discussed the different elements of the design, highlighting the changes and additions they have made to the existing curriculum, aided by visual representations of the computing curricula at the school before and after the intervention. The right hand side of the diagram, seen in Figure 5.45, shows the contributions from this project highlighted in yellow.

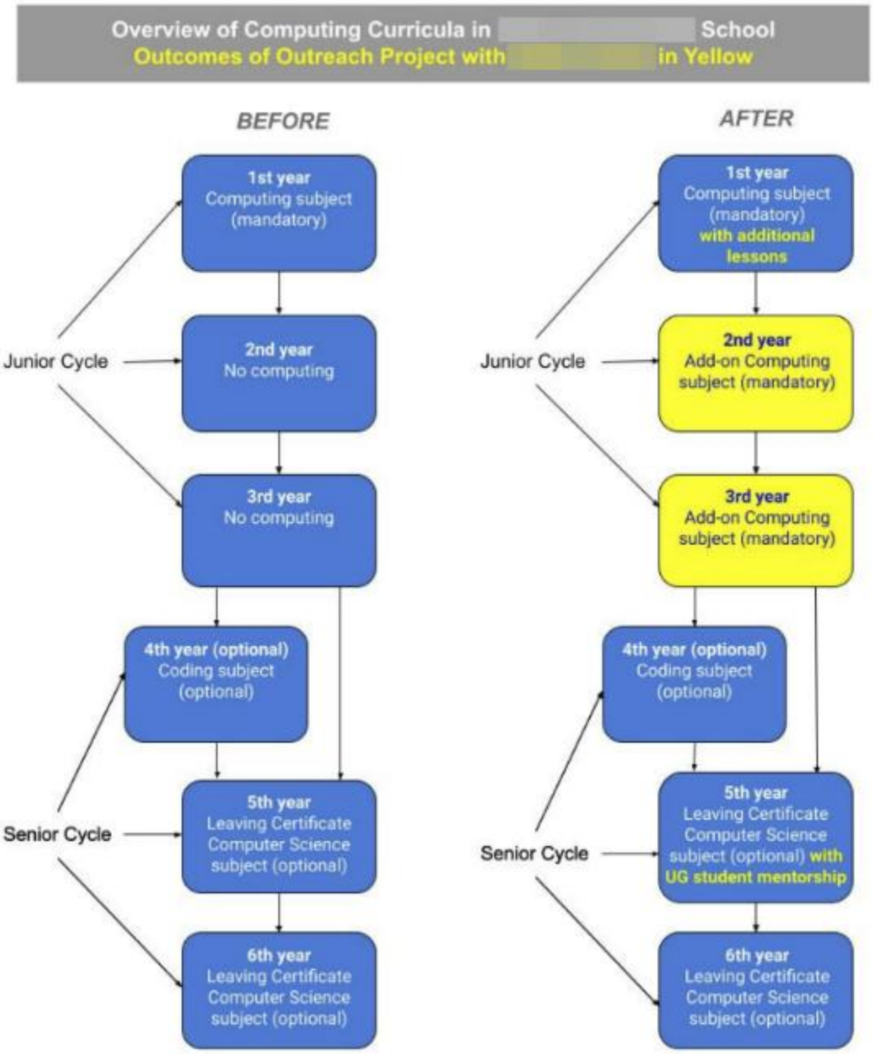
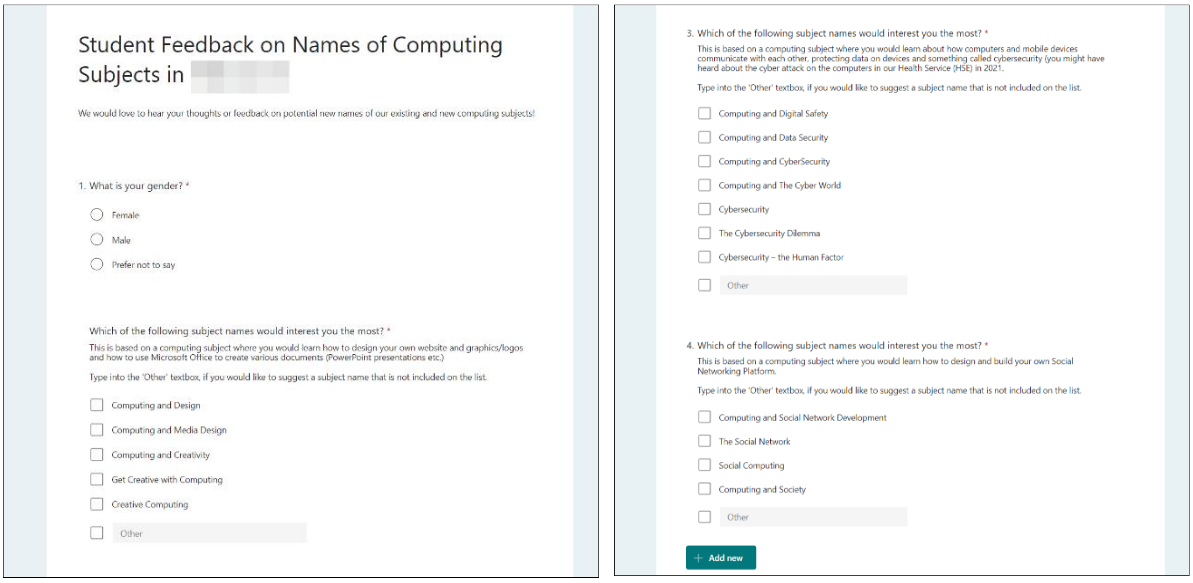


Figure 5.45: Before and after diagrams of the computing curricula in the school

The survey results from school students regarding their preferred computing subject titles in the junior cycle years were presented. The main ICT teacher explained that the anonymous survey was shared with students over a three day period in class and that 75 responses were collected. The survey, displayed in Figure 5.46, comprised four questions. The first question collected gender information, while the other three questions asked respondents to select their preferred subject titles from a list of suggested titles and descriptions based on the syllabus we designed. Additionally, students had the option to propose their own titles also.



Student Feedback on Names of Computing Subjects in

We would love to hear your thoughts or feedback on potential new names of our existing and new computing subjects!

1. What is your gender? *

- Female
- Male
- Prefer not to say

Which of the following subject names would interest you the most? *

This is based on a computing subject where you would learn how to design your own website and graphics/logos and how to use Microsoft Office to create various documents (PowerPoint presentations etc.)

Type into the 'Other' textbox, if you would like to suggest a subject name that is not included on the list.

- Computing and Design
- Computing and Media Design
- Computing and Creativity
- Get Creative with Computing
- Creative Computing
- Other

3. Which of the following subject names would interest you the most? *

This is based on a computing subject where you would learn about how computers and mobile devices communicate with each other, protecting data on devices and something called cybersecurity (you might have heard about the cyber attack on the computers in our Health Service (HSE) in 2021.

Type into the 'Other' textbox, if you would like to suggest a subject name that is not included on the list.

- Computing and Digital Safety
- Computing and Data Security
- Computing and CyberSecurity
- Computing and The Cyber World
- Cybersecurity
- The Cybersecurity Dilemma
- Cybersecurity – the Human Factor
- Other

4. Which of the following subject names would interest you the most? *

This is based on a computing subject where you would learn how to design and build your own Social Networking Platform.

Type into the 'Other' textbox, if you would like to suggest a subject name that is not included on the list.

- Computing and Social Network Development
- The Social Network
- Social Computing
- Computing and Society
- Other

+ Add new

Figure 5.46: Student survey on preferred Junior Cycle computing subject titles.

The results revealed that students unanimously selected "Computing and Design" for the first year subject title, while preferences differed between genders for the second and third year subjects. For the new second year computing subject, female respondents favoured "Computing and Digital Safety", while male respondents preferred "Computing and Cybersecurity". As for the third year computing subject, "The Social Network" emerged as the most preferred title overall.

Participants discussed the titles and the schools potential use for them. One lecturer suggested combining the different titles for the second year subject to ensure inclusivity and to capture all elements of computing, cybersecurity and digital safety.

> *"If I can make a suggestion for the second year subject, maybe just combine the two different titles. So if it's Computing, Cybersecurity and Digital Safety, then it catches everyone… and I could see why maybe females and males are interested in the different ways of referring to cybersecurity. But I think if it's got everything in there, it'll just feel like all the elements are there for all the participants"* – Lecturer 2, W6

To gain a comprehensive overview of the computing curricula if our proposed design was implemented, I introduced a new diagram (Figure 5.47) that encompassed the overall syllabus of each year, spanning from first year to sixth year. Subject titles were added, allowing us to obtain a high-level view of how the computing curricula would be structured in the school.

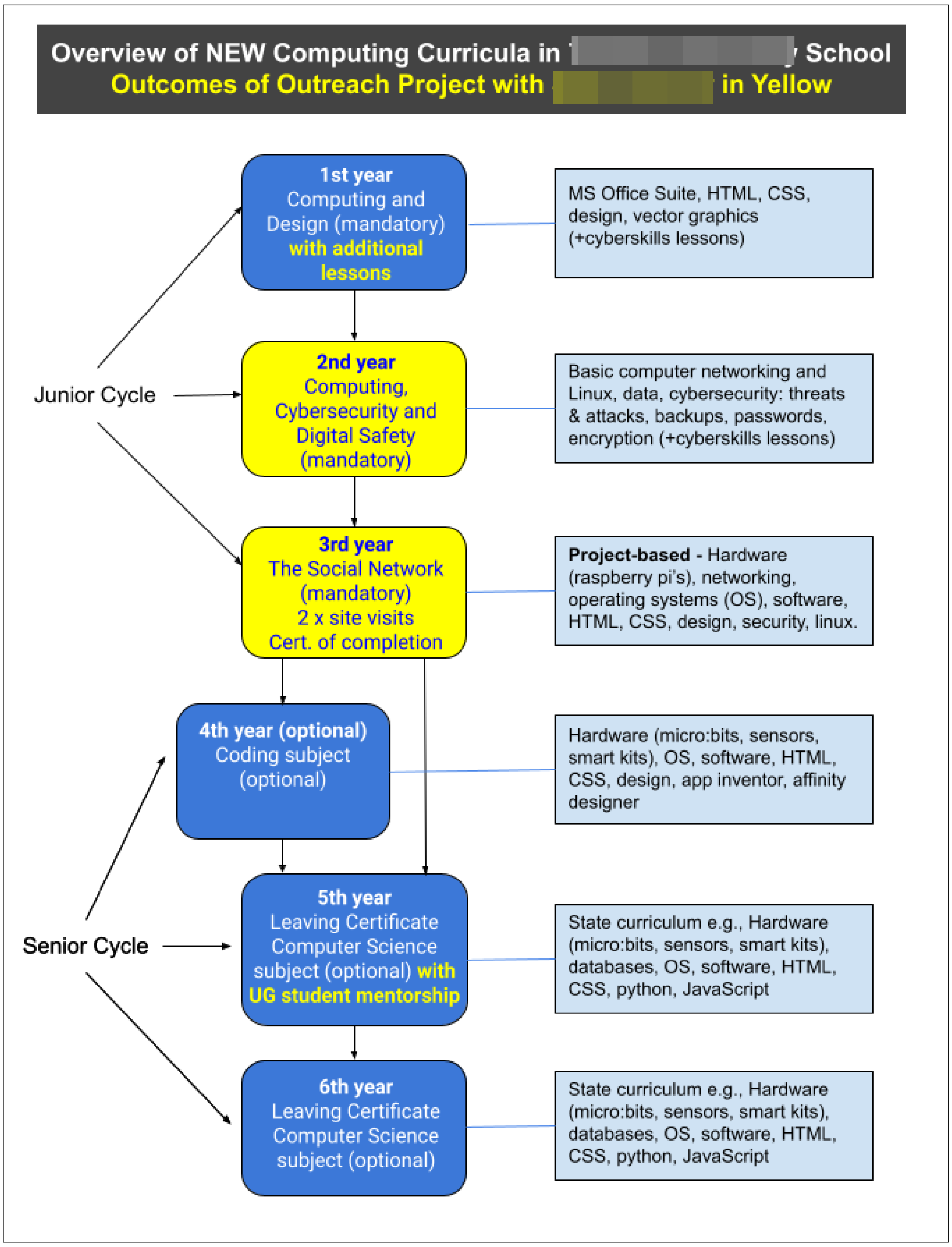


Figure 5.47: Diagram of new computing curricula with updated subject titles

Since the previous workshop, I had begun creating course material for the second year 8 week computing subject based on the indicitive syllabus suggested by the group. I proceeded to showcase a folder of structured powerpoint slides, lesson plans and activity sheets created for the school as shown being presented in Figure 5.48.

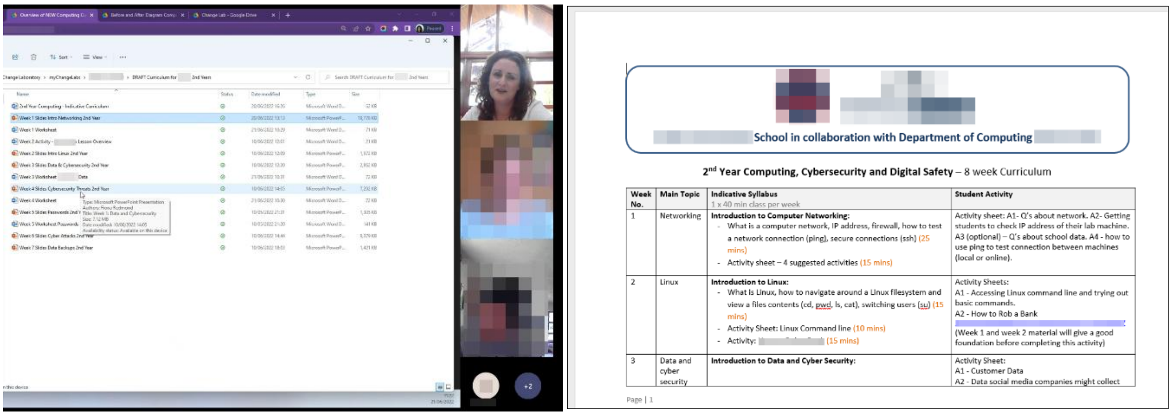


Figure 5.48: Course material for the 8-week computing course to be offered to second years

Participants discussed the course material presented and their feedback was largely positive overall. Linux was highlighted as being an important skill to learn during those activities and that knowledge will be highly beneficial for students when they later approach the third year project.

> *"I think you've done a wonderful job, what you've done, like... Emm it looks really, really positive"* – Schoolteacher 1, W6

We deliberated on the implementation approach for all components (new subjects and site visits) in the upcoming 2022/23 academic year. One option was to introduce them all at once. Alternatively, we considered a phased approach, starting with the 2nd year subject and mentorship programme in the first year, followed by the introduction of the 3rd year subject in the subsequent year (2023/24). This phased approach would ensure that 3rd year students have the prerequisite knowledge to complete their projects. Concurrently, site visits for 3rd year students would also be introduced in 2023/24 to enable project presentations on campus. We recognised that phasing in the new 2nd year curriculum would allow the ICT teacher to gradually adapt to one subject at a time, making it more manageable.

Additionally, we assessed the required number of raspberry pi units and SD cards to successfully implement the project for approximately 150 third year students. The DIRWG extended their assistance by providing some equipment to kickstart this initiative.

Lecturer 3 spoke about how the online cyber platform was incorporated into the Department of Computing's summer camp, which took place two weeks earlier. Feedback from the fourth year students who attended it was collected, and it indicated that the students enjoyed the activities and found them engaging and enjoyable. This was viewed as useful feedback ahead of the proposed design being implemented.

> "*It went very well. I think we had 40 students take those lessons. And at the end of the week, we got 96% positive feedback on the survey that we did on how it was*"
>
> – Lecturer 3, W6

Task 6B marked an exciting turning point, as it was during this task that participants had the opportunity to engage with the proposed design overall and assess its potential to address the initial needs outlined by the STEM teachers and the DIRWG. There was a positive energy as the six participants in attendance openly reflected on different aspects of the design. I also requested written answers to task 6B from the eight participants who were unable to attend and six of those participants emailed me their answers.

The twelve participants who provided feedback expressed their views, the majority of which explicitly said that they felt that the outreach initiative that we designed does meet the needs of both institutions. They expressed enthusiasm about the initiative, particularly the STEM teachers who saw in the design a powerful tool that directly tackled the challenges they faced daily surrounding computer science education in the school. The main ICT teacher expressed excitement about delivering the new computing curricula the following academic year and also highlighted positive feedback from students, particularly those who were thrilled about the continuation of computer science classes beyond first year.

> "*I'm really excited to deliver it in September… in the last couple of weeks, coming towards the end of my first year computer classes they [students] were all asking if we were doing computers again in second year and so the answer would have been no normally, but because we're doing this, they're absolutely thrilled. So, yeah really, really good. Great to keep it going*" – Schoolteacher 1, W6

> "*I believe that the initiative does meet the needs as discussed for our school. We needed something to help further the students knowledge and interest in computers from junior cycle and I believe this has been a huge help forward in doing so*."
>
> – Schoolteacher 5, W6

Similarly, DIRWG members conveyed their satisfaction with the newly design outreach initiative and expressed hope that it would positively impact gender balance in their department's computing programmes.

> "*This outreach initiative with the [school] and the [university department's] meets our requirements on many levels including: engagement with local community; second level education providers; encouraging STEM; encouraging female participation with computing and related subject matter*" – Head of Department, W6

> "*I guess our hope is that now that first, second and third years will be doing computing… that hopefully it will have a positive knock-on effect for transition year and leaving cert and that students will realise I'm really enjoying this and want to stay at it... So maybe in a couple of years, you'll notice interest increasing. The hope for us [DIRWG] is that we'll start to see a positive impact [on the gender balance enrolling on the department's computing degrees]*" - Lecturer 6, W6

> "*…it's a bit of an ongoing process and I assume that this will evolve over the years, but I certainly feel is what we have all designed, led by Fiona obviously, that we are ticking a lot of boxes from both sides, from Tullow and from Carlow. And I guess just the process that we went through to do that, to exchange the information and have that knowledge allowed us to do that, which is something I think we should point out.*"
>
> – Lecturer 5, W6

> "*I believe that the initiative meets the needs of the Department of Computing and Tullow CS by providing for students' continued engagement with formal computing studies during the junior cycle*." – Lecturer 4, W6

Some of the undergraduate students noted the proposed design has the potential to reach students who might not otherwise consider computer science and also attract more female students to the discipline. These aspects were identified as needs by both the STEM teachers and DIRWG.

> "*I've taken a look at the documents and feel that if my secondary school had offered the proposed program, I would have been very interested in it and think that some people who weren't interested in I.T might have enjoyed it too. I think it would be effective in not only*

getting young people interested in IT but also in becoming comfortable with technology and obtaining valuable skills." – Undergraduate student 1, W6

"*I would have loved if something like this was in place when I was in school! It looks to cover a lot in a very well-structured path through the years… I think this would be very interesting and beneficial to all students and it would help to maybe get more female interested and involved*" – Undergraduate student 3, W6

Participants highlighted several specific examples of needs they perceive as being met, including one identified in earlier workshops: the need to keep second and third year students engaged in computing, which they currently lack the option to do. This also addresses our need to reach students in the early years before they make their senior cycle subject choices.

"*The initiative ensures that students in Tullow CS will undertake formal computing studies in 1st, 2nd, and 3rd year. This is a considerable change to the previous provision… students in Tullow CS completed a mandatory computing course in 1st year, but no follow-on course was available during either 2nd or 3rd year. A significant interruption in formal computing studies could also possibly deterred those who were previously interested in computing from reengaging with the subject during the senior cycle of secondary school or at 3rd level.*" – Lecturer 4, W6

"*The design of the initiative is comprehensive from the perspective of delivery of computing modules to second level students. The outcome of having delivery now to every second level student year and particularly to the 2nd and 3rd year student cohorts ensure that there is a continuance of the subject prior to the delivery of the 4th year 'coding subject' option. This ensure that computing can be kept current in the students' attention and facilitates the recruitment of students to take the 'Coding subject' option*."

– Head of Department, W6

Participants also highlighted that the design should overcome a problem identified in workshop two where STEM teachers reported a difficulty in motivating students and that by offering them something to work towards such as a trip away from school. The solution within the design is the two site visits integrated into third year which STEM teachers were confident would entice students to engage and do well.

Another need participants see as being met is providing students with a genuine understanding of computer science and dispelling any misconceptions.

> *"The continued engagement with formal computing studies in 1st, 2nd, and 3rd year should allow for all students to have a greater understanding of "the varied and true nature of computer science", which is a primary aspect of the initiative's objective*. Understanding "the varied and true nature of computer science" should attract more students to consider and/or select computing as a subject during the senior cycle of secondary school and at 3rd level. " – Lecturer 4, W6

Participants also highlighted that an early workshop identified the need for an inclusive solution attractive to a diverse cohort of students. They recalled their incorporation of strategies and methods from research, which they incorporated into the design to encourage inclusive participation, particularly to attract interest from female students. It was noted that the feedback from secondary school students, obtained through anonymous surveys and informal classroom discussions with the main ICT teacher, was incorporated into several aspects of the design. The group acknowledged the positive influence of this student input on the proposed design and meeting the needs of both institutions. They hope that student input will make the design even more appealing to all school students.

> "*… the names of the subjects is something that we looked at and [lecturer 2] had a really good suggestion for including everyone to make it all inclusive for the year two subject…"*
>
> - Lecturer 5, W6

The third year project-based subject was described to be inclusive, covering a range of computing topics, and intended for a diverse student body. Students have the option to build a social network for a topic of their choice or interests.

> "*The year three subject is around the social network, which is… potentially appealing, but still true to computing.... Wasn't there discussions around research saying that female participation is more around teamwork and project-based and hands-on and creative activities, which I think our year three subject certainly has… and because it's project based*

will satisfy as well. So yeah, I think that with the hands-on stuff, I think they're just a few things that we've ticked..." - Lecturer 5, W6

"*I think… from the last years EUGAIN COST ACTION, that research came back, similar to your point [lecturer 5] that females like project-based, hands-on, working on real life problems. So what we could look at with the third year project… they're building a social network but the purpose of it could be different per group. So for them to see the overall structure would be the same they'd all be following the same steps to set it up on the Raspberry Pi and install the operating system… but then the actual design, would bring back their HTML and CSS, their graphics, and the actual purpose could be something like… climate change or sustainability, or… all genders have the option to choose a project that's solving a real world problem or something along those lines...*" – Lecturer 6, W6

"*The Social Media project idea hopefully also provides an opportunity for 15 year olds to think about how companies (Facebook, etc) i) might be using their 'real' social media app data and ii) how to re-think the app's 'features' to reward taking breaks from using tech, think about the side-effects of 'upvoting'/'liking', etc., other people's posts, maintaining streaks (and their unintended consequences); etc."* – Lecturer 2, W6

Participants recalled previous discussions about the need to reach students in the early years, before transition year and senior cycle subject choices and how schoolteacher 4 mentioned that the end goal for many students is the CAO points they achieve. It was also highlighted that parents often decide children's subjects. So upon reflection of the design now, it was said:

"… hopefully students will be going home to their parents and saying they're enjoying the computing subjects and that they'll encourage them to choose computing for the leaving cert or… to go on to study it at a third level." – Lecturer 6, W6

Further refinements were also suggested to the proposed design during this task. For example, one conversation that began with lecturer 2 inquiring about the approach employed by the ICT teacher in pairing students for activities. They questioned whether the ICT teacher decided on student groups or left it to the students themselves to form groups. Schoolteacher 1 explained their approach to pairing students for activities as depending on the specific group. Generally, it is left up to the students, except for first-year groups who may not know each other, in which case the teacher may assign them. For second and third-year groups, students typically choose their own groups since they already have established friendships. However, if a team is significantly struggling, the teacher may intervene and rearrange the groups.

Lecturer 2 offered suggestions to participants regarding potential approaches to foster inclusive participation and to sustain the motivation and engagement of female students in class.

> "*there's mixed evidence that suggests that girls are likely to be more motivated to ask questions if they're in a female group, rather than a mixed group. But if you're going to be having classes where there are boys and girls in the same class, then it may be better to pair the girls with boys, where possible, because if there's a situation where some of the male students may try to dominate, by asking all the questions, or, you know, they are always the ones who put their hands up or are less afraid to make mistakes, for instance, that we would like to be able to create an environment where female students would be able to ask questions, and feel that they can ask questions safely. And it's the same for any student really, who might be shy. So I go back to myself, I was shy, I would be reluctant to put my hand up and ask a question. But if there was somebody, you know, if I was paired with somebody I got on with and could say, oh, you know, can you ask this question? And they'd stick their hand up and ask it for me, then I get the answer I want. Yeah, you know what I mean? So I think it might be useful to look at the way that the teams are behaving as you construct them. And just if you're able to see whether the female students are less able to participate freely within the groups and maybe think of mixing it up.*"
>
> – Lecturer 2, W6

Participants concluded that ongoing consideration and monitoring of this topics and others should be ensured for the future, maintaining its status as a point of discussion during regular contact between STEM teachers and DIRWG. This recognition emphasised the necessity for continued collaboration and communication among participants to monitor the progress of the proposed design, addressing any necessary refinements as they arise.

> "*we will remain in touch, whether it's halfway through the year. One of lecturer 1's suggestions was maybe if we arranged a chat, whoever wants to be involved, maybe*

halfway through the year to see how it's going, to hear what was going well, or what's not going well, that could be tweaked. You know... if the second year curriculum is failing in certain areas that their not interested in… we could work on that… I think definitely, it would be good to keep in regular contact, whether it's once or twice a year to see how it's going or… if you need any assistance with anything that's come up… you can drop me an email and get in touch…" – Lecturer 6, W6

"*… I think the implementation of it and the feedback we get from Tullow and how it's gone, and everything like that would be, you know, fascinating, to find out how it all goes*"

– Lecturer 3, W6

"*I think it's been a really great and interesting activity to be involved in. I think it's gonna be really important for others to be able to see the kind of process that was involved in the co-creation of an outreach initiative… it's going to take a while to see if it does result in more female students engaging with computing and then eventually taking computing at third level as well. So if there is a way for Fiona, maybe to, to remain involved in this and see how it plays out over the next couple of years or longer, and that, then will provide some evidence as to how well it's working. And there's obviously opportunity for publications as well then, which I think are just as important as informing the community, and sharing the activities with others, being able to make strong claims about the actual achievements is really important as well. So well done to everybody who was involved.*"

– Lecturer 2, W6

Some participants, notably members of the DIRWG, recognised the advantages of knowledge exchange and collaboration during this design process, attributing it to fulfilling the needs of Computing Department's bespoke outreach activity system. They described how they gained insights into various aspects such as the school environment and curriculum elements like the Leaving Certificate Computer Science (LCCS) subject and the Junior Cycle, which they previously lacked familiarity with. They believed that this newfound knowledge would only enhance the department's objective of facilitating a more diverse cohort of students engaging with computing in higher education.

"*… going back to the process, I think, something that I observed… that was really good was that we didn't necessarily know what you guys [STEM teachers] were doing, and maybe the reverse is true too. So like, the knowledge that was shared. Obviously everyone's* *contributed and done a great job and Fiona has managed it and coordinated everything, and… everyone's done really good, but the information exchange, and discussing what goes on on the ground, I think that's kind of really beneficial to the design that we have.*”

– Lecturer 5, W6

“*I've learned so much about the junior cycle that I wouldn't have known because it's changed since I went to secondary school, with the profile of achievement and so on.. I've definitely learned a bit more about the Leaving Cert subject as well in the process. So I've found it really beneficial from that side. And to be able to appreciate when students come into us in first year, to know what they've gone through in secondary school. And I think knowing more about what happens in the school environment could eventually influence the design of our undergraduate computing programmes, you know like in terms of indicative syllabus and eventually previous knowledge and experience of students coming into higher education*.” – Lecturer 6, W6

This task wasn't just about celebrating the success of the proposed design. It was also a space for constructive feedback, where participants actively engaged in discussions, pinpointing areas where the design could be further refined. This collaborative spirit ensured that the proposed design would be even more impactful, resonating deeply with the needs of all stakeholders.

Participants acknowledged that while the design addresses many of the identified needs of both partners, there are ongoing issues with certain aspects of the proposed design. For example, the group observed that the design does not provide any intervention to address staffing issues for computing education in the school. However, the STEM teachers have already initiated promising discussions with school management regarding the anticipated requirement for additional ICT teachers and the potential hiring of an extra ICT teacher for the upcoming academic year.

Moreover, participants pointed out certain potential limitations regarding the feasibility of implementing some collaborative aspects of the proposed design within the academic calendar, as well as concerns about the required overhead or manpower necessary to execute them successfully.

“… there maybe a limitation with the current design of the programme and our ability to roll out a similar programme across other second level providers within the region. Principally there is a human resource requirement to manage and facilitate the delivery of the initiative and we are a small academic department where these initiatives are not

recognised within the current workload framework. Of course, once we have gone through a cycle we can review and improve and under the new Technological Universities there will be a new workload framework which should recognise these initiatives."

– Head of Department, W6

"As with many initiatives, limited human and physical resources may impact on the sustainability of the initiative. Moreover, whilst the design has taken into account the differences in university and school calendars, these conflicts may hinder the full realisation of the initiative. For example, ensuring Department of Computing undergraduate students are available consistently as mentors for 5th year Tullow CS students." – Lecturer 4, W6

Discussions during this sixth and final workshop concluded on a resounding high note.

5.3.7.3 The implications for the design

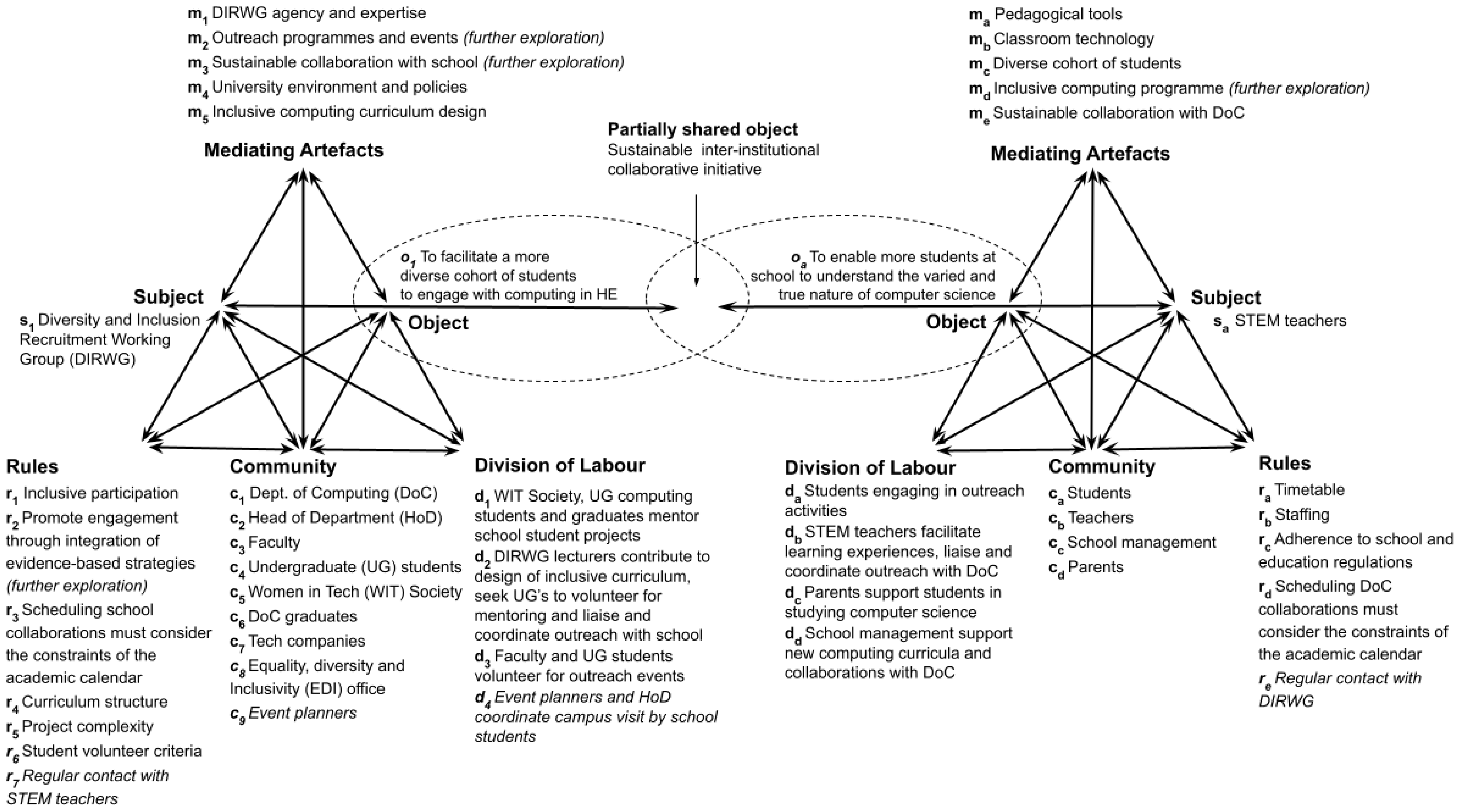


Figure 5.49: Design implications arising from workshop six

Figure 5.49 illustrates the design implications resulting from workshop six in italicised text. These implications arose when considering design implications and current practices and their rationale will now be explained.

When participants were considering the design in this workshop:

- they agreed that regular communication and collaboration between the DIRWG and the STEM teachers would be essential to ensure the smooth running of the initiative (r_7 and r_e).
- they explored design implications m_3 again. Further discussions about the site visits were had in relation to the need for the university event planners (c_{10}) and the head of department (c_2) to coordinate the campus site visit (d_4) by school students (c_a).
- they explored design implications m_d again. Further refinements were made to the inclusive computing curricula following feedback from secondary school students about preferred computing subject titles.

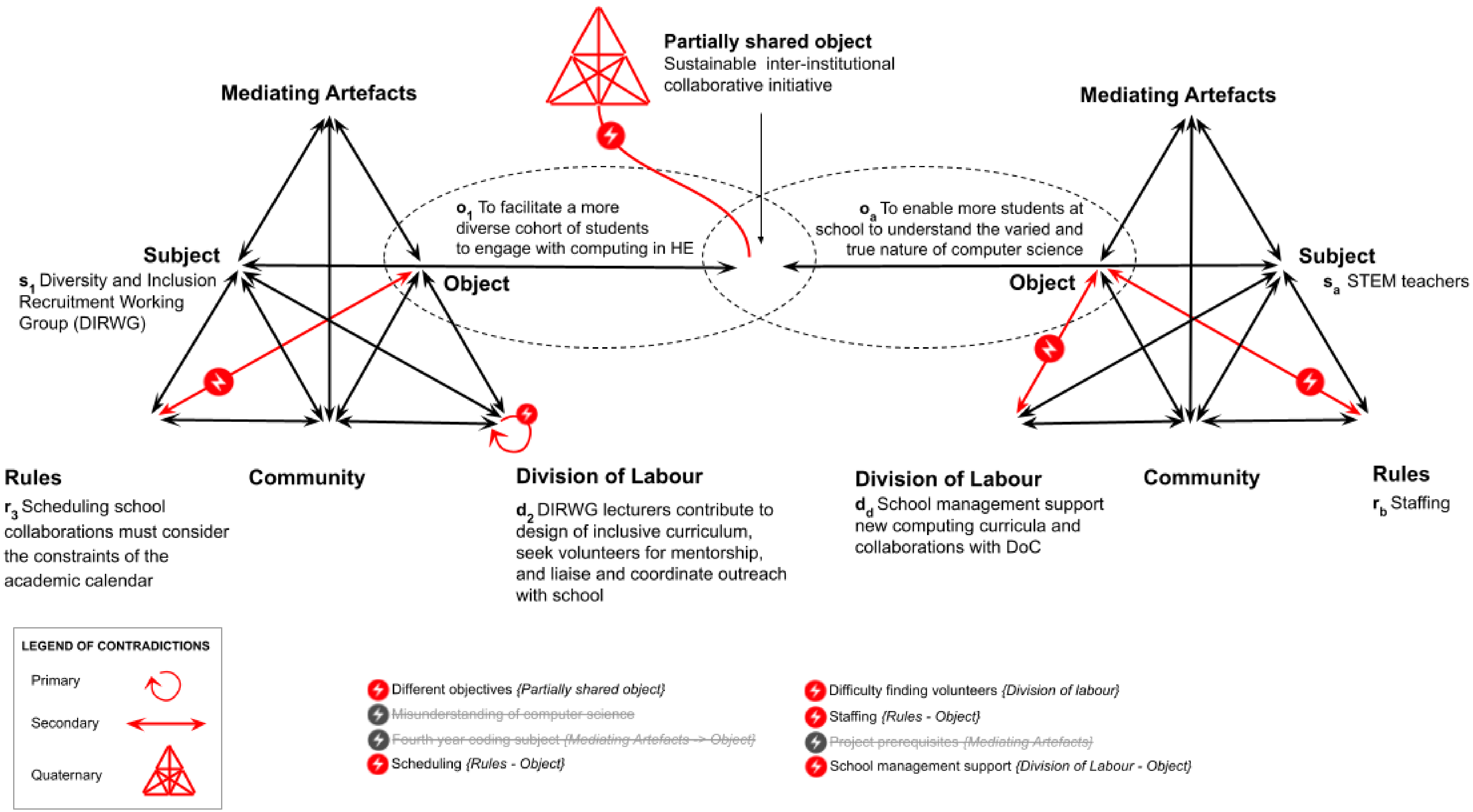


Figure 5.50: Contradictions (both existing and overcome) identified at the final stage of the design process, highlighting design implications and current practices

Three contradictions were resolved at this stage of the design process, and one new contradiction was identified. The contradictions that were overcome during workshop six are highlighted in Figure 5.50 and are described as follows:

- *Misunderstanding of computer science*. This was a tertiary contradiction identified in workshop one, occurring between the object o_a and the rules/mediating artefacts that shaped the current teaching practices. Participants felt that students often has a limited or inaccurate perception of the field, which affected gender balance and interest in continuing with the subject. This contradiction was addressed in the proposed design through the introduction of a progressive and inclusive computing curriculum across all junior cycle years, providing sustained opportunities to engage with varied aspects of computer science and fostering a more accurate understanding of the object.
- *Fourth year coding subject*. This was a secondary contradiction identified in the existing activity system during workshop two, occurring between mediating artefacts (m_a) and the object (o_a). The timing and nature of this optional subject meant it was too late in students' school journeys to significantly influence senior cycle subject choices. The contradiction was resolved in the proposed design by embedding continuous computer science engagement across the junior cycle, ensuring students develop interest and skills earlier and are more likely to choose computing in senior years.

> "*what we're doing with the lower level might impact then on that fourth year and we mightn't actually have to do anything*." – Lecturer 5, W6

- *Project prerequisites.* This was a primary contradiction identified in the existing activity system during workshop four, occurring within the mediating artefacts element itself. Third year students in the initial implementation year would lack the prerequisite knowledge and skills, having not experienced the planned first and second year computing curriculum. The contradiction was resolved by adopting a phased implementation, introducing the second year curriculum in the next academic year, followed by the third year curriculum in the subsequent year. This approach ensures that students have necessary foundations to complete the project successfully.

The new contradiction identified in this workshop is described as follows:

- *School management support*. This is a secondary contradiction identified in the school activity system during workshop six, occurring between the division of labour (d_d) and object (o_a) elements. Participants recognised that securing school management's active support and approval was critical to initiative's success. Without their backing, it would be difficult to embed the additional curriculum into existing structures or secure the resources (such as staffing) needed for effective delivery.

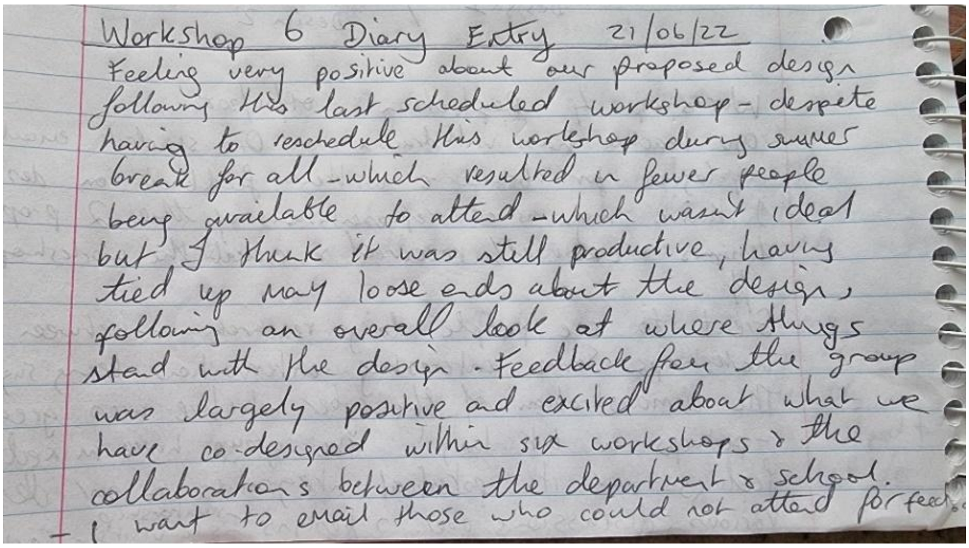
Ongoing issues with the proposed design, as illustrated in Figures 5.4 and 5.49, are described in Section 5.2.7.1.

As noted in Section 5.2.7, some contradictions, most notably school management support, remained unresolved by the end of the Change Laboratory. These were acknowledged as significant but not insurmountable. Participants expressed confidence that the initiative could and should proceed in its proposed form, with the expectation that certain tensions would be addressed in the course of real-world implementation. There was an understanding that some contradictions, such as institutional resourcing or leadership buy-in, may require longer-term negotiation beyond the scope of the CL process. Rather than undermining the project's contribution, these unresolved issues were seen as inherent to the transformative nature of the work: they signalled areas where further adaptation, advocacy, or collaboration would be necessary. In this way, the presence of unresolved contradictions was framed not as a barrier to success, but as an indicator of the ongoing, developmental journey of embedding the outreach initiative into practice.

5.3.7.4 Reflective research diary notes on workshop

Immediately following the workshop, I recorded my thoughts on this final scheduled workshop in my research diary, a sample of which is shown in Figure 5.51. I noted my satisfaction with how the workshop unfolded. For task 6A, I was particularly pleased with the use of the first-stimulus, a visualisation of the changes we had designed for the school's computer science curriculum. The "before and after" diagram effectively provoked participants into making thoughtful observations about the proposed design.

The final task, Task 6B, was designed to stimulate reflection, a key element in expansive learning. Reflection here meant revisiting the original needs identified by the STEM teachers and the DIRWG and evaluating whether the design sufficiently addressed them. I felt the mirror-data, visual representations of the current and proposed curricula, played a critical role in stimulating this reflective process. Participants actively engaged in this task, providing valuable feedback on how well the design met the goals, while also identifying areas for improvement, which demonstrated a productive and collaborative reflection process. Overall, I feel the workshop successfully prompted participants to critically assess the design's alignment with our initial objectives, reinforcing the value of this reflective stage in the co-design process.



Workshop 6 Diary Entry 21/06/22
Feeling very positive about our proposed design following this last scheduled workshop - despite having to reschedule this workshop during summer break for all - which resulted in fewer people being available to attend - which wasn't ideal but I think it was still productive, having tied up many loose ends about the design, following an overall look at where things stand with the design. Feedback from the group was largely positive and excited about what we have co-designed within six workshops & the collaborations between the department & school. I want to email those who could not attend for feed

Figure 5.51: Sample of reflective research diary notes for workshop six

5.4 Summary

The design of the outreach initiative evolved iteratively over the course of six co-design workshops (see Figure 5.52), each building on the findings and decisions of the previous, ultimately leading to the development of a progressive and inclusive computing curriculum. The initial workshops focused on identifying structural and contextual challenges within the school, including the lack of computing opportunities for 2nd and 3rd year student, fully booked timetables, and the need to create a programme that would be accessible and engaging for all students. Early ideas drew inspiration from existing creative school projects (such as Junk Kouture, and the IDAD degree), with a focus on real-world application and dual-subject titles that could align better with the school's constraints.

In Session 2, participants proposed new extracurricular interventions, such as a computer society, lunchtime clubs, and simplified project-based versions of LCCS, to enhance engagement.

However, these ideas revealed further challenges, including issues with the complexity of the existing 4th year coding subject. This led to the development of the more accessible approaches, such as mobile app design using AppInventor.

A major breakthrough occurred in Session 3 when the school proposed a solution to the timetable barrier, the introduction of a rotating 8-week block that allowed for a structured and progressive curriculum from 1st to 3rd year. This unlocked the possibility of embedding a range of topics and project-based work, including cybersecurity, into a consistent framework. Two curriculum designs were proposed and feedback sought from students to shape the final direction.

Sessions 4 and 5 focused on refining the proposed curriculum by integrating student feedback and deepening pedagogical elements. Discussions included the development of year-specific syllabi, evaluation of the online cyber platform and the selection of a diverse project idea that aligned with student interests and evidence-based teaching strategies. Notably, the integration of tools like Raspberry Pis and topics like social media and Linux were aligned with hands-on, collaborative learning goals. The team also decided to limit the use of the online cyber platform to the 1st and 2nd years to preserve a more comprehensive computer science experience in 3rd year.

By Session 6, the team had co-constructed a clear and implementable curriculum, including slides, lesson plans, and activity sheets. Further refinements were made to subject titles, based on student input, to enhance reliability and engagement. The proposed design also acknowledged the importance of school management support in ensuring sustainability through timetable integration.

This timeline of iterative design decisions shown in Figure 5.52 illustrates the collaborative and responsive nature of the co-design process, culminating in an outreach initiative that is both contextually grounded and pedagogically robust.

In summary, this chapter has presented the findings of this study by first outlining the proposed design of the joint activity system, an inclusive, progressive computing curriculum co-designed through a series of collaborative workshops and secondly by showing the design steps and process that led to the proposed joint activity system and how the design was realised by participants in the process. In the next chapter, the Discussion, I will consider findings in light of my three research questions.

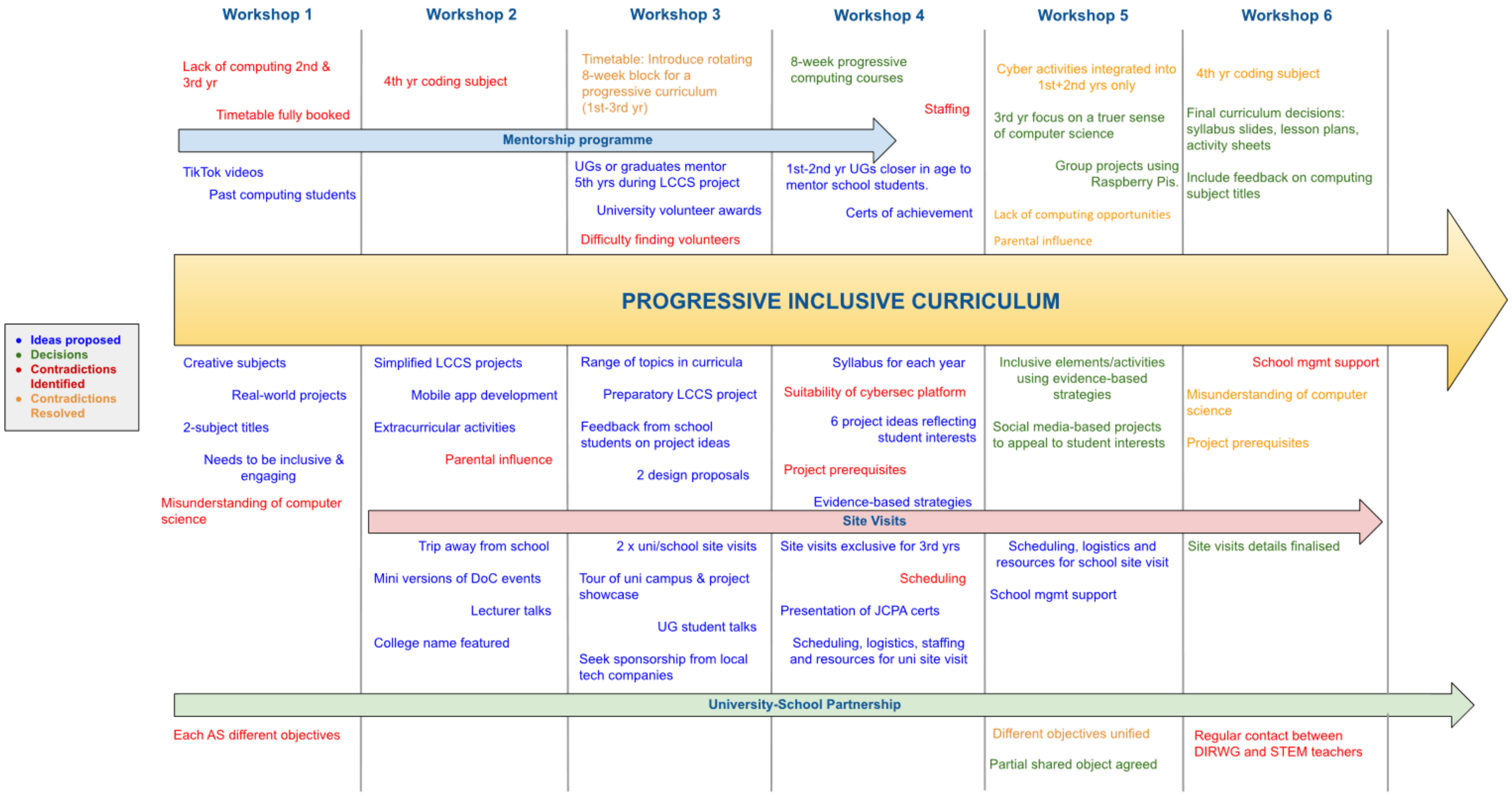


Figure 5.52: Timeline of key components throughout the design process

Chapter 6 Discussion

6.1 Introduction

The core purpose of this thesis has been to explore how outreach initiatives aimed at increasing female participation in computer science can be designed collaboratively, in response to local needs and systemic constraints. In Chapter 5,I presented the empirical findings from a Change Laboratory intervention involving secondary school teachers, university management, computing faculty and undergraduate students. This chapter moves from presentation to interpretation, offering a critical discussion of those findings in dialogue with the bodies of literature reviewed in Chapter 2.

The goal of this chapter is to examine what the findings reveal about the co-design of a context-specific outreach initiative, and how they contribute to knowledge in two areas: 1) strategies to encourage female participation in computer science education, and 2) computer science outreach design. In doing so, I engage with relevant theoretical and empirical work to articulate the implications of this study for research, policy, and practice.

The chapter is structured as follows:

> Section 6.2 synthesises the findings through the lens of the three research questions and examines what they reveal about the dynamics, challenges, and opportunities of outreach co-design within the local context.
>
> Section 6.3 then presents the study's contribution to knowledge by linking the findings back to the six themes identified in Chapter 2. This section demonstrates how the study extends, challenges, or refines current understandings of computing outreach and gender inclusion.

Together, these sections make the case for context-sensitive, co-designed, and theoretically informed approaches to outreach, particularly in computing, where dominant models have often prioritised scalability over relevance or sustainability. This discussion also aims to show how a formative intervention, grounded in activity theory, can generate insights not just about *what* to change, but *how* meaningful change emerges through collaborative processes.

6.2 Addressing the Research Questions

This section builds on the data presented and analysed in Chapter 5, to interpret how the research findings address my research questions as defined in Section 2.5. Each subsection engages with one research question and connects the empirical insights to the theoretical frameworks discussed in Chapter 2. This approach ensures a synthesis of findings with conceptual understanding, highlighting how the intervention process generated both knowledge and practical change.

6.2.1 The design of a context-specific outreach initiative

RQ1: ***What does the design of a context-specific outreach initiative aimed at increasing female participation in computer science higher education look like when collaboratively developed by multiple stakeholders?***

The outreach initiative co-designed during this research intervention emerges as a tailored, multi-dimensional model aimed at increasing female participation in computer science by leveraging the strengths and resources of multiple stakeholders. This sustained, multi-year model echoes the call in Lang *et al.* (2020) and Kim *et al.* (2023) for long-term interventions over one-off events, which have been shown to produce limited and short-lived effects. Unlike the traditional one-off programmes or short-term activities described in existing literature, which often lack depth and sustained engagement, this initiative is a sustained, context-specific progressive inclusive curriculum that spans the first three years of each student's full-time education in a single school. Each year's syllabus builds progressively upon the previous one, providing students with a continuous experience in computing, building their skills and engagement. It also addresses several key challenges and contradictions present in the local context. Figure 6.1 outlines a simplified version of the joint activity system with contradictions, as previously shown in Chapter 5. It shows the outreach initiative designed and proposed by participants from the University and School partnership.

The outreach initiative designed is not an event, it is a ***progressive inclusive curriculum***, a comprehensive educational programme designed to provide students with a deep understanding of computing over several years. This approach aligns with Sentance and Csizmadia's (2017) emphasis on integrating computing into mainstream curricula, but differs in that it was generated through a co-design methodology rather than being imposed from a national policy level. This long-term approach allows for continuous engagement and exposure fostering a more profound connection with the subject. By delivering the curriculum through familiar schoolteachers within the students' own setting, the programme promotes comfort and reliability, thereby enhancing student engagement and learning outcomes. The curriculum is designed collaboratively with input from various key stakeholders, ensuring it reflects local needs. Such local tailoring is often absent from national or regional outreach initiatives (Lang *et al.*, 2015), which can limit their relevance and sustainability. This localised design is critical in addressing contradictions identified by stakeholders in the current computing education practices in the school, as well as contradictions that emerged during the design process.

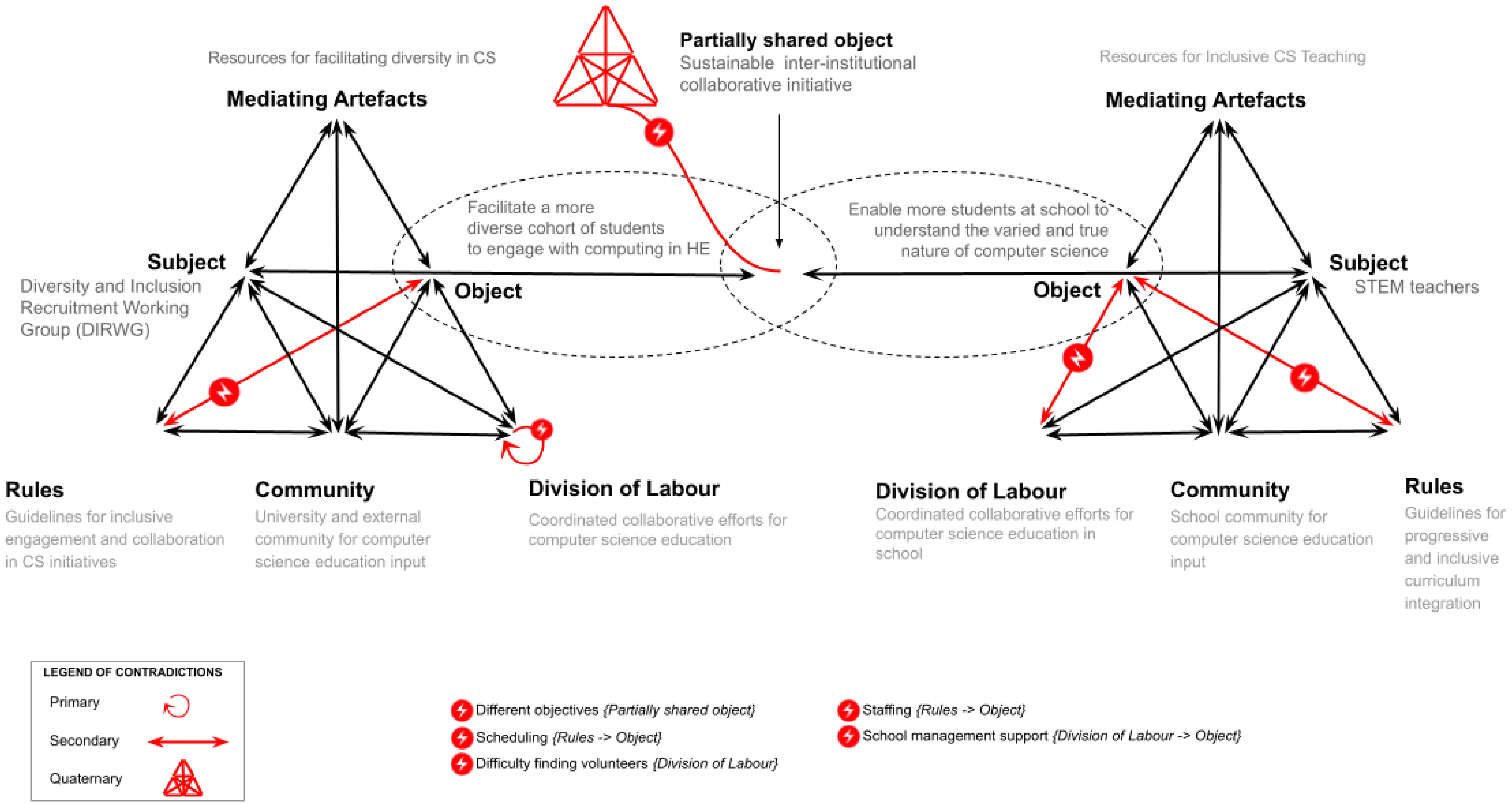


Figure 6.1: Simplified design of the proposed joint activity system with contradictions

Unlike existing outreach programmes typically designed solely by academic groups, this initiative emerged from a co-design process involving key stakeholders from the university's computing department and the local school. This responds to the gap identified by Goode *et al.* (2012) for more participatory models that position local schools as equal partners rather than passive recipients of university outreach. This collaborative approach allowed for the creation of local solutions to local problems, ensuring that the initiative was tailored to the specific educational context and needs to the students.

The outreach initiative is positioned to address both structural barriers (such as curriculum gaps and resource limitations) and cultural barriers (such as gender stereotypes in computing). In this respect, it reflects the dual emphasis on structural and cultural change discussed by Goode *et al.* (2012) but demonstrates a concrete, context-bound pathway for achieving both simultaneously. By providing a structured, long-term engagement in computing, it not only demystifies the subject but also fosters a more inclusive atmosphere that encourages female students to envision themselves as future computer scientists.

This initiative breaks down the barriers of traditional computing education by highlighting the diverse opportunities within the field, showcasing not just coding but also aspects like creativity, problem-solving, and collaboration. This broader framing echoes findings from UNESCO (2017) on the importance of exposing students to the breadth of computing roles to counter narrow stereotypes. By presenting computing as a multifaceted discipline, the initiative seeks to attract a broader range of students, particularly females who may have previously felt excluded.

This collective approach not only enhances the quality of the outreach programme but also promotes a sense of local ownership, as stakeholders are invested in the initiative's success. The design process was critical in ensuring that the solutions produced were acceptable to both the university and the school involved and the students. By meeting the needs of all stakeholders, the initiative is more likely to gain acceptance and be sustained over time, ensuring its long-term impact on female participation in computer science.

The design's focus on a long-term educational journey rather than isolated events allows for deeper learning and integration of computing education into the school. This contrasts with the short-term gains but long-term drop-offs noted in Lakanen and Kärkkäinen's (2019) evaluation of game programming outreach interventions. As students progress through the curriculum, they build on their knowledge and skills increasing their confidence and interest in pursuing computer science in senior years of school and beyond in higher education.

The participants believe that this outreach initiative which they co-designed, represents an advancement in the approach to increasing female participation in computer science education. By focusing on a progressive, tailored curriculum delivered within the familiar context of the students' school, and through a collaborative stakeholder engagement process, it offers a programme that addresses local needs and promotes sustained engagement.

6.2.2 The process and interactions involved in developing the initiative

RQ2: ***What processes and interactions shape the collaborative development of a bespoke outreach initiative aimed at increasing female participation in computer science higher education?***

The design of the bespoke outreach initiative aimed at increasing female participation in computer science higher education was shaped through a dynamic, iterative process involving multiple stakeholders. Such co-design processes reflect the participatory design traditions outlined by Sanders and Stappers (2008) yet are relatively rare in computing outreach, where top-down models remain the norm. This co-design approach was instrumental in ensuring the initiatives alignment with local needs and challenges.

The foundation of the initiative's design was established through a series of structured workshops where participants, including university management, faculty and students and schoolteachers, came together to co-design the outreach programmes. During these workshops participants collectively *identified contradictions* with current computer science education in the school, such as the lack of computing opportunities in second and third year. Similar contradictions have been documented in UK secondary schools by Sentance and Csizmadia (2017), though their study found fewer opportunities for resolution due to top-down curriculum constraints, highlighting the flexibility afforded by a localised co-design. These workshops created a shared understanding of the challenges, which was essential for framing the outreach initiative. Participants proposed potential solutions, drawing on their unique expertise and perspectives. For instance, schoolteachers spoke of their experiences with students and school resources while the university faculty highlighted the need to show students the true and varied nature of computer science.

This echoes Goode *et al.* (2014) findings that teachers' insights into local student needs are crucial for designing interventions that resonate with underrepresented groups.

The co-design process was structured around five of the seven expansive learning stages, questioning, analysis, examination, modelling and reflection, some stages of which were in an iterative cycle where ideas and solutions were refined through ongoing discussions and feedback. As Bligh and Flood (2015) observe in their analysis of Change Laboratory interventions in higher education, such processes rarely unfold in a strictly linear fashion; rather, they often involve recursive movements back to earlier stages as participants collectively refine and reframe emerging solutions. This cyclical approach facilitated the dynamic evolution of the initiative. Early versions of the initiative's curriculum and activity structure were proposed based on the initial workshops. For example, participants initially proposed titles of the three computing subjects to be offered to first, second and third years. These proposed titles were then presented to key stakeholders, including school students, who provided crucial insights into how they perceived the proposed titles and they had the opportunity to propose titles they felt would be more effective and appealing. This feedback revealed important preferences, which informed subsequent iterations. This step mirrors participatory design's emphasis on end-user validation (Spinuzzi, 2005), here applied in a school setting.

The iterative nature of the process allowed the design team to adapt to practical constraints identified during feedback sessions. For instance, challenges such as academic calendar alignment and staffing limitations at the school level led to adjustments in scheduling of site visits and curriculum integration. This ongoing feedback loop ensured that the design remained responsive and flexible. This reflects the balancing act between ideal design and feasible implementation observed in other collaborative curriculum design projects (Voogt *et al.*, 2016).

The collaborative development process was characterised by the integration of diverse perspectives from various stakeholders, each contributing unique expertise and resources. University management, faculty and students working closely with schoolteachers to align the curriculum with both university policies and the secondary school's educational standards. This close collaboration ensured that the curriculum would be feasible for implementation and relevant for students, effectively bridging the gap between secondary and tertiary education. The involvement of undergraduate computing students was pivotal in integrating mentorship and role modelling components into the initiative. Previous research, such as that by Lang *et al.* (2020), highlights the power of near-peer role models in fostering belonging and interest among younger students, particularly for girls in STEM. Their engagement not only addressed the need for female representation but also provided insight into what motivates school goers to pursue computing careers. Their participation created a pathway for undergraduate students to connect with and inspire school students, which became a cornerstone of the proposed outreach model.

As the process unfolded, stakeholders encountered and negotiated contradictions inherent in the outreach initiative. During the workshops, these contradictions were not only discussed but also actively resolved where possible, which was crucial to moving the design forward. For example, the contradiction between the academic calendars of the school and the university required negotiation and strategic planning to align the site visits and mentorship school visits with critical decision-making periods for school students (e.g., choosing senior cycle subjects). This resolution illustrates Engeström's (2001) argument that contradictions can serve as catalysts for innovation when surfaced and addressed collectively. By recognising these contradictions as opportunities for growth, the design team was able to build synergies between different activity systems. This included finding common ground between the school's objectives of enabling more students at school to understand the varied and true nature of computer science and the university's objectives of facilitating a more diverse cohort of students to engage with computing in higher education. This synergy was crucial in ensuring that both systems worked toward the shared objective of a sustainable inter-institutional collaborative initiative.

The collaborative development of the outreach initiative was an intricate, multi-layered process that combined structured workshops, iterative prototyping, and the integration of diverse stakeholder insights. This approach demonstrates the practical value of Change Laboratory methodology in outreach contexts, an application area that remains underexplored in the literature. This co-design process approach allowed for dynamic adaptation, ensuring that the initiative was responsive to both structural and socio-cultural factors. The processes and interactions that shaped the initiative reveal how meaningful stakeholder engagement and collective problem-solving are essential in developing sustainable, context-specific outreach interventions aimed at increasing female participation in computer science. Future research could examine how such processes unfold over multiple years, particularly in relation to sustaining cross-institutional collaboration beyond the initial intervention period.

6.2.3 Contextual opportunities and constraints

RQ3: What do the outcomes and processes of designing a context-specific outreach initiative reveal about the potentialities and constraints within the local context for increasing female participation in computer science higher education?

The outcomes and processes of designing the context-specific outreach initiative reveal a dynamic interaction between existing constraints and emerging potentialities within the local educational context for increasing female participation in computer science. This balance of constraints and affordances resonates with the ZPD framing applied in educational change research (Daniels, 2008), where current capacity is extended through collaborative intervention.

Figure 6.2 outlines the crucial differences between existing practices and potential new practices structured in parallel to Vygotsky's Zone of Proximal Development (ZPD).

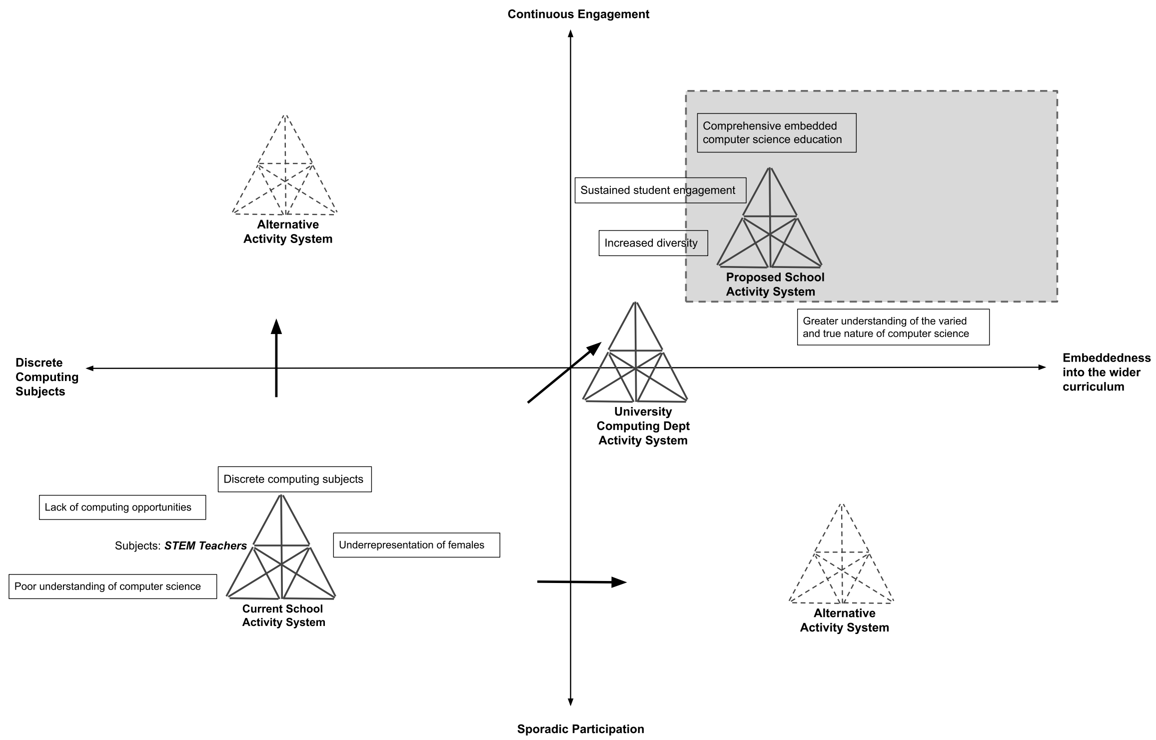


Figure 6.2: The zone of proximal development of school's activity system

The ***Current School Activity System***, positioned in the bottom left of the ZPD diagram, reflects the existing educational setup in the school where computing education is discrete and involve sporadic participation. These computing subjects fail to capture the interest of diverse student groups, particularly females. This mirrors findings from Serussi and Divitini (2017) on the risks of marginalising computing as an optional or peripheral subject. The fragmented structure results in a lack of continuous exposure to computer science, limiting student engagement and their understanding of the field. This state is largely sustained by individual efforts from teachers. This area of the diagram reveals several **constraints** within the local context such as structural gaps where the curriculum is discrete and isolated, particularly in second and third years, limiting sustained exposure to computing concepts. Another constraint is resource limitations where the school has insufficient resources (e.g., timetable hours, computing teachers) required for effective computing education. Such resource constraints have been identified internationally (OECD, 2021) as major barriers to equitable access in computing education. These constraints contribute to the underrepresentation of females in computing and highlight the need for a transformation that moves beyond individual actions toward an integrated, institutional approach.

The ***Alternative Activity System*** (top left of Figure 6.2) shows an intermediate state where computing education remains a discrete subject but is marked by regular and collaborative activities, serving as a transitional phase toward a fully embedded curriculum. In this phase, collaborative efforts between STEM teachers and the university's Diversity and Inclusivity Recruitment Working Group (DIRWG) lead to mentorship programmes, along with campus visits to both the school and university. These initiatives aim to sustain interest and gradually build momentum, showcasing a partial integration that increases computing exposure despite the subject remaining outside the core curriculum.

At this stage, the potentiality lies in achieving higher engagement levels within the existing curriculum structure, with collaborative projects and hands-on activities building relevance and familiarity with computing concepts. The feedback loops generated from these activities allow stakeholders to refine and tailor sessions for maximum engagement, even within the limitations of a discrete subject structure. However, logistical challenges, such as aligning academic calendars and ensuring the consistent participation of both school and university staff, present obstacles that can impact sustainability. The system remains reliant on available resources and the active involvement of specific personnel, suggesting that while engagement and collaboration are increasing, the absence of a fully integrated curriculum creates a need for substantial support to maintain ongoing efforts.

Ultimately, this alternative activity system embodies a key transitional pathway, where foundational gains in engagement and familiarity with computing can prepare students and faculty for the move toward a fully embedded curriculum model. The progression through this phase highlights the essential role of cross-institutional collaboration, as it provides a glimpse into the possibilities of a more cohesive and integrated approach.

The ***Alternative Activity System*** (bottom right of Figure 6.2) represents a phase where early attempts to integrate computing into the curriculum are underway, yet student engagement remains sporadic. Similar "early embedding" stages have been documented by Voogt *et al.* (2016), who caution that without long-term institutional support, such integration risks regression to isolated initiatives. This state signifies an initial embedding of computing education into the broader curriculum, where collaborative work between the school and university begins to solidify. Here, stakeholders, including university faculty and STEM teachers, work toward embedding computing across all junior cycle years, ensuring no gaps in computing exposure during second and third years and promoting a stable, baseline presence of computing within the educational experience.

While student engagement remains inconsistent at this stage, certain incremental steps, such as cross-curricular projects linking computing with other subjects, could serve to lay a foundational familiarity with computing concepts. These interdisciplinary connections create relevance within the broader curriculum, providing initial exposure that may foster a gradual increase in student interest and comfort with computing, even before engagement reaches a sustained level. This phase also presents an opportunity to build readiness within the school's culture for the anticipated future state of continuous, collaborative engagement.

The sustainability of this early embedding is, however, challenged by the sporadic nature of student involvement, which can impede momentum for further integration. As a result, continued support and structured collaboration between school and university stakeholders become essential to maintaining these early curriculum advancements. The bottom-right system thus captures the beginning stages of curriculum integration, where significant groundwork is laid that, although modest in impact, establishes a critical foundation for sustained engagement in computing education in the future.

The ***University Computing Department Activity System*** is crucial here; it supports the development of curriculum materials and provides undergraduate mentors to school students. However, the impact is still limited by inconsistencies in student participation and the ongoing struggle to align educational schedules and priorities between the institutions.

The ***Proposed School Activity System*** (top right) represents the desired outcome: computing fully embedded in the wider school curriculum, with continuous, engaging, and collaborative computing activities for students. This vision reflects international recommendations for inclusive computing education (Royal Society, 2017), but its local co-design origin marks a distinctive methodological contribution. This state is the target zone within the grey area, indicating the system’s potential evolution into an integrated and sustained model for computing education. Here, the initiative has achieved a state where computing is no longer an isolated subject; instead, it is woven into the educational fabric, ensuring ongoing exposure and engagement.

The ***grey box*** or area in the top right denotes the target zone for the initiative’s development, a zone of proximal development, signifying the potential trajectory of the school’s computing education system as it evolves towards the desired state. The grey dotted boundary around this grey area represents flexibility and openness to varied outcomes. It acknowledges that while there is an overarching aim for a progressive and inclusive computing curriculum embedded into the wider school curriculum for sustained engagement, other schools may adapt this differently to fit their specific needs and contexts.

The ***arrows*** depict the multiple pathways of evolution, showcasing how the school’s system could move through intermediary states. For instance, the arrow from the Current School Activity System (bottom left) to the Alternative Activity System (top left), illustrates a phase where computing remains a standalone subject, but the programme begins to foster more consistent student involvement. This represents early interventions by individual schoolteachers and initiatives that gradually build engagement, indicating the initiative's responsiveness to existing conditions. The arrow from the Current School Activity System (bottom left) to the Alternative Activity System (bottom right) involves embedding computing in the curriculum but requires ongoing efforts to increase consistency in student participation. And the arrow moving directly from the Current School Activity System (bottom left) to the future state (top right), represents the progressive and comprehensive curriculum integration and sustained engagement achieved through continued collaboration between the university and school.

The outreach initiative has shown that the ZPD within the local educational environment can be expanded when multiple stakeholders collaborate effectively. This expansion exemplifies Engeström's (2001) concept of moving the “actual” activity system toward the “potential” through sustained collective effort. The initiative connected the university’s computing department and a local secondary school, thus creating a network of support that extending beyond the capabilities of each educational institution working in isolation. This network enabled the co-design of a computing curriculum that was context-specific, bridging the gap between secondary and tertiary education. By aligning the school's needs with the university expertise, the outreach initiative demonstrated how institutional collaboration can expand educational offerings and opportunities for female students, pushing the boundaries of what was previously possible. By integrating mentorship programmes, site visits and hands-on projects, the initiative established new and continuous learning pathways that extended the school's computing curriculum. These pathways enable female students to engage with computing not as a one-time event or subject but as an on-going educational journey, thus enhancing their engagement and understanding. This continuity represents an expanded ZPD where the local context adapts to offer sustained, evolving educational experiences.

6.3 Contribution to Knowledge

In this section, I demonstrate how my research findings contribute to the two key areas of literature reviewed in Chapter 2, strategies to encourage female participation in computer science and computer science outreach design. I revisit the six themes within these areas, highlighting the significance of my findings in the context of the existing literature. I begin with a summary of these contributions in Table 6.1, organised by the research areas and themes outlined in Chapter 2.

Table 6.1: Summary of contributions to research knowledge

Research area	**Theme**	**Contribution**
Strategies to encourage female participation in computer science education	Early exposure	• to provide insights into linking early exposure programmes with long-term support mechanisms, such as mentorships, to maintain interest and sustained engagement.
	Short immersive interventions	• to explore the integration of a sustainable intervention embedded into local resources and culture.
	Specialised curriculum approaches	• to explore the integration of progressive and inclusive curricula that offer a comprehensive overview while engaging specific interests.
Computer science outreach design	Scalability	• to demonstrate the potential for context-specific interventions that can be designed to complement local resources and cultural dynamics, showcasing how outreach initiatives can be successfully designed for diverse educational settings.

	Sharing of outreach initiative design	• to provide detailed documentation of the outreach design process to help other outreach designers anticipate or navigate similar challenges in their own contexts. • to demonstrate how the identification of contradictions in the design process can enable designers to make informed decisions when designing outreach initiatives in their own context.
	Outreach designer expertise	• to explore how diverse expertise and inclusive design processes can enhance the cultural relevance and sustainability of outreach initiatives, showcasing collaborative approaches.

6.3.1 Contribution to the literature on strategies to encourage female participation in computer science education

6.3.1.1 Early exposure

My main contribution here is *to provide insights into linking early exposure programmes with long-term support mechanisms, such as mentorships, to maintain interest and sustained engagement*. While the literature reviewed in section 2.3.1 highlights the critical role of early exposure in shaping girls' interest in computer science (Gürer and Camp, 2002; French and Crouse, 2018), it often overlooks the challenge of maintaining that initial interest as they progress through their education. My research addresses this gap by proposing an outreach initiative that bridges early exposure with ongoing support mechanisms, particularly through a progressive inclusive curriculum over the first three years of secondary school, ensuring that the early interest is nurtured into long-term engagement.

In line with studies that highlight challenge-based learning as an effective early exposure strategy (Denner *et al.*, 2005; Şahin Timar and Mısırlı, 2023), my findings incorporate similar methods (e.g., online cyber platform activities) within the outreach initiative but with an added emphasis on continuity. Furthermore, the literature advocates for presenting computer science as an enjoyable and creative pursuit, challenging traditional perceptions of the field as a solitary, male-dominated activity (Yates and Plagnol, 2022; Anderson *et al.*, 2008). In response, my research incorporates these ideas by using collaborative, enjoyable activities such as university campus site visits and social media projects but ensures this approach is maintained over time. Furthermore, mentors act as ongoing role models, helping girls see the subject as accessible and challenging stereotypes about the field. Going forward, my research suggests that integrating early exposure with continuous support, such as mentorships and inclusive curriculum progression, is essential to fostering sustained interest among girls in computer science. This approach emphasises that early exposure alone may not be sufficient; instead, a structured pathway that incorporates ongoing support and visibility of diverse role models is necessary to counteract gender stereotypes and promote long-term engagement. The implications of my work suggest that future research should focus on testing and refining models that pair early exposure with longitudinal support mechanisms, with particular attention to how these interventions impact girls' sustained interest and self-efficacy in computer science over time.

6.3.1.2 Short immersive interventions

My main contribution here is *to explore the integration of a sustainable intervention embedded into local resources and culture*. The literature reviewed in section 2.3.2 highlights that short immersive interventions are a strategy used for encouraging female participation in computer science education. These interventions, which include workshops, coding competitions, summer camps, and hackathons, aim to create an immediate impact by providing concentrated bursts of exposure and hands-on experience within a limited timeframe. Research shows that well-structured programmes with clear objectives and engaging activities can significantly enhance students' interest and confidence in computer science (Eidelman *et al.*, 2011; Kaval *et al.*, 2024).

Despite their strengths, short immersive interventions often struggle to maintain momentum after the event concludes. The limited duration can hinder in-depth skill development and sustained behavioural change, leading to a perception that these experiences are isolated rather than part of a larger journey in computer science. My research addresses these shortcomings by creating a continuum of engagement that sustains the initial interest sparked by these interventions. Moving forward, my work implies that short-term programmes would benefit from being embedded within a broader, culturally relevant framework that leverages local resources, such as partnerships with schools, to promote sustained interest and skill-building. I argue that future research should further investigate the benefits of embedding short-term interventions within ongoing support networks and local cultural contexts, which could transform the traditional model of short immersive outreach into a more integrated, long-term support mechanism for female students in computer science.

6.3.1.3 Specialised curriculum approaches

My main contribution here is *to explore the integration of progressive and inclusive curricula that offer a comprehensive overview while engaging specific interests.* The literature reviewed in section 2.3.3 highlights the value of specialised curriculum approaches in attracting female students to computer science by focusing on topics like web development, robotics, or game design (Jamshidi *et al.*, 2024; Roscoe *et al.*, 2014; Sharma *et al.*, 2021). However, my research addresses the shortcoming in ensuring these specialised topics also contribute to a broader understanding of the field, helping students acquire foundational skills necessary for long-term participation in computer science.

Aligned with studies that emphasise interest-driven learning, such as using game design or creative projects to introduce computer science concepts (Webb *et al.*, 2012; Buffum *et al.*, 2015), my findings support the idea that these approaches are effective at sparking initial interest. For example, my research shows that hands-on, project-based learning in areas like social media themed development projects provides female students with an accessible entry point, making the subject less intimidating. However, my findings also suggest that while these interventions capture interest, they need to be complemented by a more comprehensive curriculum to ensure long-term engagement and skill development.

Additionally, while the literature often advocates for creative, focused projects to make computer science appealing (Mladenović *et al.*, 2016), my research highlights the importance of ensuring that students are introduced to the full spectrum of computer science, including but not limited to coding. Building on the work of Şahin Timar & Mısırlı (2023), the participants of this project found that introducing diverse areas within computer science, such as web development, cybersecurity, Linux and networking, helps female students find a field they resonate with, fostering a sense of belonging and sustained interest. My findings emphasise the need for gender-neutral, inclusive project design to avoid reinforcing narrow interests and to broaden the appeal of computer science. Moving forward, this research suggests that to fully engage female students, curriculum designers should consider not only interest-specific modules but also a holistic progression that gradually builds both skills and confidence. I argue that future outreach programmes should prioritise diverse, integrative curricula that reveal the expansive possibilities within computer science, thereby fostering both immediate interest and a pathway for long-term involvement in the field.

6.3.2 Contribution to the literature on computer science outreach design

6.3.2.1 Scalability

My main contribution here is *to demonstrate the potential for context-specific interventions that can be designed to complement local resources and cultural dynamics, showcasing how outreach initiatives can be successfully designed for diverse educational settings.* Existing literature which I reviewed in section 2.4.1, often emphasises the importance of scalability (Craig and Horton, 2009; Lawlor *et al.*, 2020), however, the participants of this study found that scalability should not be pursued at the expense of local relevance. For instance, while a standardised model may work well in urban schools with ample resources, it often fails to translate effectively to rural or underserved communities with different technological access and cultural attitudes. This echoes the findings of Lang et al. (2015), who noted that the outcomes of their scalable programme varied significantly based on local factors like school culture and teacher engagement.

Furthermore, my research identifies the importance of designing outreach initiatives tailored specifically to fit local cultural and institutional needs. This builds on Sauppé et al. (2015), who acknowledge the necessity of customising outreach lessons to align with local resources. Through these findings, I argue that rather than viewing scalability solely in terms of expansion, future outreach efforts should focus on designs that consider the diverse needs of educational communities. This research indicates that a flexible, context-sensitive approach not only respects local dynamics but can also enhance the reach and effectiveness of outreach initiatives. Going forward, I suggest that research on scalable outreach models should prioritise adaptability over uniformity, thus supporting educational equity by ensuring all students have meaningful access to computer science education, regardless of their context.

6.3.2.2 Sharing of outreach initiative design

My first contribution here is *to provide detailed documentation of the outreach design process to help other outreach designers anticipate or navigate similar challenges in their own contexts*. While much of the literature reviewed in section 2.4.2 tends to focus on final outcomes or high-level descriptions of outreach activities (Lau *et al.*, 2009; Gottipati *et al.*, 2018), my research offers a more transparent account of the design stages, trade-offs, and contextual decisions involved in creating a successful initiative. By detailing not just what was done but how and why specific decisions were made, I fill a gap in the current scholarship, which often lacks insights into the iterative process behind programme development. My work addresses this need by providing comprehensive documentation of how challenges, such as resource limitations, participant diversity, or logistical constraints, were managed and resolved. This process-oriented narrative serves as a practical guide for others seeking to design effective outreach initiatives, enabling them to better anticipate obstacles and make informed design choices.

My second contribution is *to demonstrate how the identification of contradictions in the design process can enable designers to make informed decisions when designing outreach initiatives in their own context.* In practice, outreach designers often face competing demands, such as balancing engagement with educational depth, or tailoring programmes to specific groups while maintaining scalability. These contradictions are not always addressed in the literature, which tends to present outreach initiatives as linear, one-dimensional efforts (Sauppé *et al.*, 2015; Huggard and Mc Goldrick, 2006).

My research reveals how acknowledging and strategically addressing these contradictions, whether related to resource allocation, target audience engagement, or balancing local adaptation with replicability, can lead to more robust and contextually appropriate outreach designs. For example, I show how recognising the tension between scalability and local specificity led to the creation of adaptable programme components that could be customised for different educational settings. By highlighting the value of confronting these contradictions head-on, I offer a framework that allows outreach designers to refine their own programmes through a more reflective, problem-solving approach. This process-oriented contribution emphasises the importance of adaptability, resilience, and transparency in programme design, encouraging future research to focus not only on successful outcomes but also on the often-complex pathways leading to them, thereby equipping designers to make more contextually aware and sustainable outreach decisions.

6.3.2.3 Outreach designer expertise

My main contribution here is *to explore how diverse expertise and inclusive design processes can enhance the cultural relevance and sustainability of outreach initiatives, showcasing collaborative approaches.* While existing outreach efforts often rely on the technical and academic expertise of a small group of designers (Huggard and Mc Goldrick, 2006; Eidelman *et al.*, 2011), my research highlights the need for a more inclusive approach that brings in diverse perspectives from local communities, educators, and students. This collaborative method not only improves the alignment between outreach programmes and the cultural and educational contexts they are designed for but also fosters greater buy-in from those communities. By integrating local voices into the design process, my findings suggest that outreach programmes can become more sustainable and better equipped to address the unique needs and aspirations of their target audiences.

In contrast to the literature reviewed in section 4.3.3 that often describes outreach initiatives as top-down processes led by university experts or industry professionals (Lau *et al.*, 2009; Denning *et al.*, 2013), my research demonstrates the value of co-creation with local stakeholders. By actively involving faculty, students and teachers in the design process, outreach designers can better understand the specific challenges and interests of the communities they aim to serve. For instance, in my study, the inclusion of local teachers in the design phase ensured that the curriculum addressed relevant educational goals, while feedback from students helped refine activities to be more engaging and relatable.

This approach contrasts with the more insular design models frequently documented in the literature, where programmes are created based primarily on the designers' technical expertise and assumptions about what will engage students (Lang *et al.*, 2015). By engaging a wider range of expertise, outreach initiatives can better reflect the cultural and social realities of their intended participants, enhancing their long-term impact. My findings underscore the need for a paradigm shift toward inclusive design processes in outreach, advocating for a model that sees local community members not just as participants but as co-designers. Future research should further investigate how such collaborative models can foster sustainable partnerships and greater adaptability in outreach programmes, ultimately promoting a more grounded, community-centred approach to computer science education.

6.4 Summary

In the first part of this chapter, I have synthesised the findings from Chapter 5 to address my research questions, focusing on how the co-design of an outreach initiative aimed at increasing female participation in computer science education. This synthesis provided a detailed examination of the proposed design that emerged from the collaboration between participants and the design process that led to that design.

In the second part of the chapter, I outlined my contributions to the bodies of knowledge discussed in Chapter 2. By mapping the findings to the themes in the literature, I demonstrated how my work extends current discussions on strategies to encourage female participation in computer science education and computer science outreach design.

In the following chapter, I will present my conclusion, where I will reflect on the overall findings and how they align with the research questions and objectives set out at the start of this thesis. I will also outline the study's limitations, consider the implications for future practice, and suggest areas for further research.

Chapter 7 Conclusion

7.1 Introduction

In this chapter, I begin in Section 7.2 by revisiting the research objectives of this study and the approach taken to achieve them. In Section 7.3, I summarise the key findings, discussing how they respond to the research questions and contribute to the broader discourse. In Section 7.4, I reflect on the limitations of the study, considering their implications for the interpretation and applicability of the results. Sections 7.5 and 7.6, explore its implications for policy and practice, focusing on its tangible impacts. Finally, in Section 7.7, I outline the study's contributions to knowledge and identify potential areas for future research.

7.2 Research Objective

This research set out to examine how co-design processes influence the development of outreach initiatives aimed at increasing female participation in computer science (CS) education. While much of the existing literature focuses on outreach strategies such as early exposure, short-term interventions, and specialised curricula, there is limited exploration of how these approaches can be tailored to specific local contexts through collaborative design. This study contributes to the literature on gender equity in CS education by critically analysing how co-design can be leveraged to develop sustainable and context-sensitive outreach initiatives.

By documenting the complexities of the co-design process, including the contradictions and iterative refinements that shaped the initiative, this research advances the scholarly understanding of how participatory design methodologies, particularly the Change Laboratory approach, can support the development of outreach initiatives that are inclusive of ways that are grounded in and responsive to the local context. The study extends existing work on outreach design by demonstrating how stakeholder collaboration and expansive learning cycles contribute to identifying and addressing barriers to female engagement in computing education.

Through an interventionist approach, this research aimed to generate theoretical and empirical insights into the dynamics of collaborative outreach design. While the locally designed CS initiative was developed as a tangible outcome, the primary scholarly contribution lies in analysing the co-design process itself and its influence on outreach effectiveness and stakeholder engagement.

7.3 Research Findings

The findings address the three research questions by (1) identifying the key components that stakeholders developed in the initiative's design, (2) examining the processes and interactions that shaped its development, and (3) exploring the contextual factors that influenced the initiative's structure and potential for implementation. Rather than evaluating the impact of the intervention after implementation, this research focused on understanding how an outreach initiative can be designed in ways that are responsive to local needs and challenges. Through a structured co-design process, stakeholders collaboratively developed an initiative that was shaped by the constraints and opportunities within the local educational environment.

For RQ1, which examined the components that shaped the initiative's design (discussed in Section 6.2.1), findings indicate that stakeholders proposed a structured, progressive educational model rather than a one-off outreach event. Unlike conventional outreach efforts that often focus on short-term engagement, this initiative was intended to be embedded within the school curriculum and developed as a sustained programme spanning three years. The phased approach was intended to allow for continuity, enabling students to build upon their computing knowledge over time and fostering deeper engagement.

A critical aspect of the initiative's design was its potential for integration into the secondary school environment, with the intention of aligning with existing educational structures while addressing key gaps in computing education. Stakeholders prioritised delivery through familiar schoolteachers and supplemented learning with mentorship from university students. This structure was intended to create an inclusive learning environment where female students could envision themselves pursuing computing-related studies and careers. Additionally, the initiative was designed to broaden perceptions of computing beyond programming by incorporating elements of creativity, problem-solving and interdisciplinary applications, making the field more accessible and appealing to a wider range of students.

For RQ2, which explored how the co-design process shaped the initiative (discussed in Section 6.2.2), findings highlight the importance of structured, iterative collaboration in developing a meaningful and contextually relevant outreach model. The Change Laboratory approach facilitated expansive learning actions including questioning, analysis, modelling, evaluation and reflection, allowing stakeholders to iteratively refine the initiative based on feedback and emerging insights. The process fostered a strong sense of local ownership, which was essential in ensuring the proposed programme's relevance and feasibility.

Schoolteachers brought insight into student needs and institutional constraints, while university faculty contributed CS education expertise. Undergraduate computing students also participated in the co-design process, and their perspectives were seen as valuable by the group. As young adults who had recently transitioned from secondary school to higher education, and who represented both male and female experiences, there were able to contribute insights grounded in their own educational journeys. The co-design process also surfaced contradictions within the existing education system, such as misalignment between school and university schedules, which stakeholders collectively navigated to develop a more integrated approach. These collaborative efforts demonstrate how institutional partnerships can drive meaningful change in CS education accessibility.

For RQ3, which examined the opportunities and constraints within the local context (discussed in Section 6.2.3), findings reveal how structural barriers, including limited timetable hours, a shortage of computing teachers, and fragmented computing education, posed challenges in developing a fully integrated curriculum. These constraints emphasised the need for sustained institutional support and cross-sector collaboration to ensure long-term success.

At the same time, the research identified key opportunities for transformation. The university-school partnership provided a support network that extended beyond the capacity of each institution individually, allowing for the development of a more cohesive computing education experience. By aligning school curriculum needs with university expertise, stakeholders were able to propose expanded opportunities that had previously been limited. The inclusion of mentorship, hands-on projects, and site visits was envisioned to help bridge the gap between secondary and higher education, facilitating a more continuous learning pathway for students.

Overall, the findings of this research suggest that a co-designed, context-specific, and sustained approach has substantial benefits in the development of outreach initiatives aimed at increasing female participation in CS. The initiative's design was shaped through iterative collaboration, addressing both structural and cultural barriers to education. While challenges remain, findings suggest that they can be navigated through sustained partnerships, institutional support and a strategic approach to curriculum integration.

7.4 Limitations

This study encountered several limitations that shaped the research process and findings. While these constraints influenced aspects of data collection and analysis, they also provide important insights into the complexities of co-designing outreach initiatives in real-world educational settings.

One limitation is the challenge of balancing the operational requirements of both the university and school, which at times conflicted with the research objectives. Co-ordinating schedules between South East Technological University (SETU) and Tullow Community School required ongoing negotiation, and logistical constraints, such as class timetabling, teacher availability and resource allocation, restricted the flexibility of certain activities. The necessity of fitting research interventions within predefined academic calendars is a constraint that future co-design projects in education are also likely to face and should consider carefully. In this case, the time-bound nature of the project limited opportunities for more iterative engagement and adaptive refinement of the initiative. This may have influenced the findings by making the co-design process more structured than it might have been in a setting with greater flexibility. Future research could explore how a more extended timeframe might allow for deeper iterations and responsiveness to emergent insights. Nevertheless, the findings remain a meaningful reflection of how outreach can be co-designed with practical, real-world constraints.

A related limitation arises from the use of the Change Laboratory methodology itself. While it provided a powerful structure for facilitating expansive learning, it also depended heavily on participant engagement across multiple sessions. This led to some variability in attendance and participation, particularly when constrained by institutional timetables or competing priorities. As a result, some sessions yielded richer data than others, and this variability may have influenced the consistency of insights across the process. However, the methodology still enabled a collaborative design process in which key stakeholders contributed meaningfully to shaping the outreach initiative. This experience highlights an important consideration for other researchers using similar approaches, ensuring consistent engagement across multiple sessions can be challenging in education settings and requires careful planning, flexibility and institutional support.

Another limitation concerns participant availability, particularly among female undergraduate computing students. The limited number of female students who participated in this study reflects the wider gender imbalance in computing programmes. While both male and female undergraduate students contributed valuable insights, especially given their recent experience transitioning from secondary to third-level education, the relative absence of female voices may have constrained the depth of understanding regarding the role of gendered experience in shaping computing identity. Future research would benefit from engaging a more diverse group of female participants to better explore how gender influences perceptions of computing and outreach design.

The intended scope of this study is also an important consideration. From the beginning, the research was designed to explore the co-design phase of outreach development, rather than its long-term impact or implementation. While the resulting curriculum has since been embedded across the junior cycle at Tullow Community School, this study does not include longitudinal data on outcomes such as Leaving Certificate Computer Science subject uptake or university enrolment in computing programmes. As such, it cannot make claims about the sustained impact of the intervention. Future research could build on this work by tracking student outcomes over time to assess how co-designed outreach efforts influence engagement, choice, and persistence in CS education. However, the absence of this long-term evaluation does not diminish the study's central aim, to analyse the design process and the collaborative practices that enabled context-sensitive outreach to emerge.

Another limitation relates to how the concept of agency was addressed in this study. In Change Laboratory interventions, co-design is often understood as a process where participants gradually develop a stronger sense of transformative agency, meaning their capacity to question existing practices, envision alternatives, and initiate change (Engeström and Sannino, 2010; Haapasaari *et al.*, 2016). While this idea informed the overall design of the project, I did not specifically analyse how participants' agency developed over time. This leaves room for future research to explore how agency emerges during co-design processes, particularly by looking at how participants express ideas, challenge assumptions, or suggest new directions as the work unfolds (Sannino, 2010).

Finally, some readers may view the study's local focus as a limitation in terms of generalisability. Because this initiative was deeply embedded within a particular university-school partnership, questions may arise about whether its findings are applicable elsewhere. However, this project was not intended to produce a universal model. Rather it aimed to demonstrate the value of designing outreach initiatives in response to local needs and constraints. The co-design process and methodological approach offer a framework that is transferable across settings, even as specific programme designs may differ. The emphasis on context does not undermine the broader relevance of the findings, it reinforces the need for adaptable, locally grounded outreach models that can be shaped by the communities they serve.

7.5 Implications for Policy

As I argued in Section 1.3, while global, national and institutional policy frameworks have made important strides in acknowledging gender imbalances in STEM, their capacity to enact meaningful change in computer science (CS) education is often limited by a lack of context sensitivity. This research reinforces that critique by demonstrating that effective interventions must be attuned to the specific, localised challenges experienced by female students and educators in CS. Rather than simply improving the implementation of existing frameworks, this study suggests that many of those frameworks themselves require rethinking, particularly their reliance on top-down, standardised models that fail to engage with the lived realities of the classroom or community.

A key insight from this study is that broad, one-size-fits-all approaches to gender balance often fail to address discipline-specific barriers, particularly in computer science. For instance, participants in this research identified male-dominated classroom dynamics, a lack of female role models, and minimal early exposure to computing as key deterrents to girls' participation in CS. These issues were not peripheral but central to how young women made sense of their non-belonging in computing spaces. While global frameworks such as the United Nations Sustainable Development Goals (SDGs) and UNESCO's "Cracking the Code" report foreground gender equity in STEM, they often lack the granularity needed to address the unique cultural and pedagogical issues within CS. This research therefore contributes to global policy discussions by demonstrating the value of interventions that are not only STEM-oriented but tailored to the cultural and pedagogical particularities of computing education. It also aligns with broader calls for context-aware, civically embedded education strategies, as exemplified by the Morecambe Bay Curriculum (Garrett and Nelkon, 2024), which argue for transformation through local engagement rather than top-down directives alone.

At the national level, Ireland's STEM Education Policy Statement (2017-2026) promotes early engagement and cross-sector collaboration. However, as Section 1.3 also noted, the policy's broad orientation towards STEM can obscure the distinct needs of specific disciplines like CS. This project identified a persistent shortcoming between the aspirational goals of national policy and the day-to-day experiences of students and teachers. Participants in this study, for example, consistently highlighted the importance of sustained rather than one-off engagement and advocated for gender-sensitive curriculum design that show the true and varied nature of computer science, not just the cool exciting aspects. Their feedback directly informed the co-design of an outreach initiative that moved beyond short-term coding events to focus instead on progressive skill development and inclusive pedagogies. This model suggests that national policy should not only encourage early outreach, but also support the formation of structured, multi-year partnerships between higher education institutions (HEIs) and schools that enable sustained, locally designed interventions.

Institutionally, the Athena Swan Charter provides an important mechanism for promoting gender equity across HEIs in Ireland. Yet as discussed in Section 1.3, its emphasis on quantitative metrics and institutional benchmarks risks marginalising the qualitative experiences of students and staff. This project found that context matters deeply. For example, during the co-design process, schoolteachers identified the lack of familiarity with computing, and narrow perceptions of what CS entails as key barriers to student engagement. These are the kinds of local insights that are often invisible in national or institutional policies to be more than compliance exercises. They must be responsive to local realities and grounded in the voices of those they aim to support. A purely metric-driven approach cannot capture the full complexity of why certain groups remain underrepresented in CS.

Furthermore, HEIs should be encouraged and resources to develop outreach initiatives that are not only recruitment-focused but embedded in broader institutional commitments to cultural and pedagogical change. In this study, for example, the outreach initiative was not an isolated intervention, it was interwoven with discussions about local classroom dynamics, curriculum design, mentorship programmes, campus and school site visits, and sustainable partnership models. These elements point to the kind of systemic, institution-wide engagement that is necessary for policy to have more than a symbolic impact.

Across all levels of policy, a recurring challenge is the tendency to favour scalable, standardised interventions that promise efficiency but often fails to translate across diverse educational contexts. This research argues instead for a shift towards localisation, ecological fit, and stakeholder agency. Policies should empower those at the coalface, teachers, students, community actors, to shape the design and delivery of gender equity initiatives. As this project illustrates, meaningful progress is more likely when interventions emerge from the bottom up, shaped by the knowledge and experiences of those directly affected.

Finally, the participatory nature of this research itself offers important policy lessons. Participants reported that the co-design process gave them a sense of ownership, helped surface challenges that had previously gone unspoken, and fostered deeper engagement with the intervention. These findings suggest that policy frameworks should not only enable local action but actively centre participation as a core principle. Doing so can help bridge the gap between high-level strategy and classroom realities, not by demanding conformity to rigid models, but by opening space for creativity, responsiveness and context-sensitive innovation.

7.6 Implications for Practice

My study offers several implications for how gender equity initiatives in computer science (CS) education can be practically designed within school-university partnerships. As outlined in Chapter 6 and grounded in SETU's longstanding commitment to regional education and outreach, my findings reinforce the value of sustained, context-sensitive and co-designed interventions in supporting increased female participation in CS.

A key implication emerging from this work is the importance of long-term, embedded outreach initiatives, rather than relying on isolated or one-off interventions. The outreach initiative developed through my study was co-designed by stakeholders to unfold progressively over a three year period, with clear integration into the school's curriculum. This structure was intended to support ongoing engagement and allow for the gradual development of students' confidence and interest in computing, particularly among girls, by moving beyond short-term exposure to CS concepts. Since the conclusion of the data collection phase of my research, the three-year progressive curriculum has been fully implemented at Tullow Community School across first, second and third year (junior cycle). Feedback from participating schoolteachers has been overwhelmingly positive, with strong indications that student engagement, especially among girls, has increased significantly. This reinforces the practical benefits of designing school-based computing interventions that are responsive to local contexts and co-designed with educators who understand their students' needs.

The formal launch[9] of our co-designed outreach programme in April 2024 further illustrates how HEIs can provide continued support beyond the research phase. My visit to the school alongside my Head of Department to officially launch the programme and donate Raspberry Pi's to support the third year curriculum (see Figure 7.1) demonstrated how institutional backing can extend the life and impact of research-led initiatives. Such gestures, while partly symbolic, also represent tangible demonstrations of institutional commitment and highlight the importance of visible, sustained partnerships between HEIs and schools in fostering meaningful change in computing education.

Figure 7.1: Launch of the outreach initiative at Tullow Community School, 29th April 2024. Pictured (L–R): Fiona Redmond (researcher and lecturer, SETU), Cleona McCann (ICT teacher and participant, Tullow Community School), and Nigel Whyte (Head of Computing, SETU and participant). Names and roles used with permission; student faces blurred for anonymity.

---

[9] https://www.linkedin.com/posts/south-east-technological-university_setu-setu-empowers-female-students-to-study-activity-7294642175466721280-Xl0g; https://www.setu.ie/news/setu-empowers-female-students-to-study-computer-science

My research suggests that practice-driven interventions may be most meaningful when they are locally responsive and shaped by the realities of their educational context. The co-design process enabled both university and school partners to navigate institutional constraints and collaboratively identify feasible entry points for change. For example, one key moment in the collaboration involved working through the challenge of scheduling university site visits to align with the schools subject choice timelines, highlighting how responsiveness to school structures contributed to shaping a viable and contextually grounded outreach model. The programme's sustainability has been underpinned by the continued collaboration between SETU and Tullow Community School, where participants understood from the outset that it's success would depend on ongoing partnership, shared responsibility and mutual trust.

Another key implication relates to the role of outreach designers and educators in shaping how computing is perceived by students. The co-design process revealed a shared desire among participants to shift student's perceptions of what computer science actually involves. Rather than perpetuating the view of CS as purely technical or solitary, participants emphasised its creative, collaborative, and real-world problem-solving dimensions. This finding suggests that gender equity in CS is not solely about increasing participation, it is also about reimagining the discipline itself. HEIs must not only embed gender-sensitive pedagogies in their outreach and curricula but also work to dismantle exclusionary narratives about CS by developing more inclusive representations of what computing entails.

Furthermore, my study illustrates how regional HEIs such as SETU can act as drivers of systemic change by building sustainable school partnerships and facilitating regional networks. The success of this co-designed initiative helped catalyse the development of the Cyber Schools Initiative[10], which has since expanded to 20 schools and engaged approximately 1,500 students in cybersecurity-focused outreach [11]. This initiative, supported by Calmast, Cyber Ireland's South-East Chapter, and a range of industry sponsors, represents a direct extension of the values and approaches cultivated through this research. As part of the initiative, I visited schools across the region to deliver sessions that introduced hands-on cybersecurity concepts and explored careers in computing (see Figure 7.2). This ripple effect demonstrates how co-designed, contextually

[10] https://cyberskillslive.com/schoolsireland/
[11] https://www.setu.ie/news/setu-launches-cybersecurity-programme-for-secondary-schools

grounded outreach initiatives can serve as prototypes for regional ecosystem development, provided they receive continued institutional and community support.

Figure 7.2: The author presenting to school students as part of the Cyber Schools Initiative (left) and promotional advertisement for the initiative (right).

In summary, my study reinforces the value of long-term, partnership-based approaches to outreach that are grounded in the realities of local contexts. It illustrates how HEIs, through meaningful collaboration with schools and communities, can play a pivotal role in transforming both gender equity in CS and broader perceptions of the discipline. By embedding outreach within sustained, co-designed structures, HEIs can contribute not only to increased participation, but also to the redefinition of what computer science is and who it is for. These findings resonate with broader international research into school-university partnerships as sites of expansive learning, where systemic change emerges through co-configured practices across diverse educational contexts (Hopwood *et al.*, 2024a).

7.7 Implications for Future Research

This research makes valuable contributions to both the literature on strategies for encouraging female participation in computer science education and computer science outreach design. As outlined in Chapter 6, the study provides new insights into the effectiveness of long-term support mechanisms, the integration of culturally relevant interventions and the role of inclusive curriculum designs. This section details these contributions, structured around the key themes identified in the Discussion chapter.

Linking early exposure with long-term support mechanisms: While existing literature recognises the importance of early exposure in sparking interest in computing (French and Crouse, 2018; Gürer and Camp, 2002), this study extends this discussion by demonstrating that early exposure alone is insufficient. My findings suggest that stakeholders viewed initial interest in CS as something that should be sustained through ongoing structures, such as mentorship and progressive curriculum integration, to maintain engagement over time. This contribution helps bridge a shortcoming in outreach design by linking early-stage interventions to longer-term participation strategies.

Embedding sustainable interventions within local contexts: This study explores how outreach initiatives can be designed to align with local resources and cultural frameworks to enhance their sustainability. While many interventions such as workshops and hackathons, operate as standalone efforts aimed at generating immediate interest (Eidelman *et al.*, 2011; Kaval *et al.*, 2024), the outreach initiative in my study was deliberately co-designed by stakeholders to be embedded in the school's curriculum and institutional rhythms. Although not evaluated longitudinally, the design was intended to promote ongoing relevance and engagement. This contribution highlights the importance of leveraging existing partnerships, such as school-university collaborations, to ensure initiatives remain locally meaningful and structurally embedded.

Developing progressive and inclusive curriculum approaches: Existing studies have examined interest-driven learning and curriculum adaptations to engage female students (Barker and Aspray, 2013; Denner et al., 2014). My findings build on this literature by illustrating how a co-designed curriculum can introduce CS topics progressively while incorporating inclusive pedagogical strategies. Importantly, participants in this study sought to move beyond coding-focused models by including creative, interdisciplinary and real-world applications. While the long-term effects remain to be evaluated, the initiative was designed to support both sustained engagement and broader access to diverse career pathways in CS.

Designing context-specific outreach models: While scalability is often framed as a key objective in outreach literature (Craig and Horton, 2009; Lawlor *et al.*, 2020), my findings suggest that context-sensitive outreach models, designed collaboratively and grounded in local needs, cultures and resources, may be not only more effective but more appropriate. Rather than aiming for uniform replication, outreach efforts might benefit from locally driven discussions about how best to support female participation in computing. In this view, each setting becomes a site of design in its own right, with stakeholder agency at the centre. This contribution reframes scalability not as expansion, but as responsiveness, where impact grows through relevance, not standardisation.

Documenting outreach design for future practitioners: While much of the outreach literature focuses on programme outcomes, my study contributes a detailed, process-oriented perspective on the design of an outreach initiative. By tracing the development of the initiative, including constraints, trade-offs, and participant contributions, my research provides detailed insights that can inform future outreach efforts. This contribution highlights the value of making the outreach design process more transparent.

Identifying contradictions to inform outreach design: This research demonstrates how contradictions within the outreach design process can be leveraged as opportunities for refinement and innovation. Rather than viewing challenges as barriers, my findings illustrate how identifying and resolving tensions, enables designers to make informed decisions. This contribution provides a practical framework for other outreach designers to navigate similar challenges in their own contexts.

Enhancing cultural relevance through diverse expertise: Traditional outreach initiatives often follow a top-down, expert led approach (Lau et al., 2009; Denning et al., 2013). My research challenges this model by illustrating the benefits of incorporating diverse expertise, including teachers, undergraduate students, university staff and management, as co-designers in outreach programme development. Although the long-term outcomes are still unfolding, the design process itself was perceived by participants as inclusive and grounded in local experience. This study contributes to the growing body of research advocating for participatory and community-driven approaches to outreach.

In summary, this research offers significant contributions to the understanding and practice of computer science outreach by addressing key shortcomings in sustainability, inclusivity, and context-sensitive design. By illustrating the importance of linking early exposure with long-term support, embedding initiatives within local contexts, and adopting co-design approaches, this study provides a holistic framework for developing effective and locally grounded outreach programmes. Additionally, the findings challenge existing standardised models by advocating for adaptable and transparent outreach design processes that prioritise cultural relevance and gender balance.

As I outlined in Section 1.5, existing literature documents the persistent gender disparities in computer science education and the limitations of conventional outreach approaches in addressing these issues. By directly responding to these shortcomings, this study contributes new perspectives on designing equitable and context-sensitive outreach interventions that are deeply embedded within local educational ecosystems. These findings resonate with broader calls to design tools and activity systems for learning that emerge through collaborative processes grounded in participants' contexts (Bligh, 2024), and align with recent reviews of Change Laboratory practices in school settings (Hopwood, 2024).

My study opens up several important avenues for future research in the areas of gender imbalance in computer science (CS) education and outreach design. As noted in Section 7.4, one key limitation of this project was its focus on the design phase of the intervention rather than its long-term implementation. While the co-designed curriculum has since been embedded across first, second and third year at Tullow Community School, my research did not evaluate its long-term impact. Future studies should address this shortcoming by tracking student engagement, Leaving Certificate subject uptake, and subsequent enrolment in third level CS programmes over time. Longitudinal research would offer a more comprehensive understanding of the sustained impact of context-specific outreach efforts.

Another significant area for future research involves tension between traditional models of computing education and more progressive, inclusive outreach strategies. As discussed in Chapter 6, this study identified a tertiary contradiction between the newly co-designed curriculum and pre-existing computing offerings in the school, such as the less popular fourth year coding subject. Future research could explore how to redesign or align these existing subjects with the three year progressive curriculum in previous years to reduce fragmentation and ensure progression and continuity of engagement across year groups.

Several of the contributions discussed in Section 6.3 also suggest specific directions for future investigation. For example, future research could explore how early exposure programmes might be more effective when explicitly linked with long-term mentorship and curricular integration. As I argued in Section 6.3.1.1, early interventions alone are unlikely to sustain interest unless supported by ongoing structures and relationships. Similarly, building on Section 6.3.1.2, future work could investigate how embedding short-term activities into local cultural and institutional contexts, like the integration of site visits, mentorship, or school-based projects, can enhance their relevance and effectiveness.

The research also highlights the potential for collaborative approaches in designing culturally relevant outreach. Future research might build on this by further examining how co-design processes involving teachers, students, and community members can be used in different educational settings, particularly those with limited access to computing resources or where gender stereotypes remain deeply embedded.

Finally, future work should also explore the role of contradictions in outreach design. As I showed in Section 6.3.2.2, recognising and working through tensions, between scalability and specificity, or between institutional constraints and outreach goals, can help designers to make more grounded and adaptive decisions. Future researchers could adopt contradiction mapping as part of their outreach design process to support adaptive responses to context-specific challenges.

In conclusion, while this study represents a significant step forward in designing co-created, context-specific outreach initiatives to address gender imbalance in CS, it is only the beginning. Future research should continue to explore how sustained, participatory interventions can be evaluated and refined in ways that remain faithful to local needs and inclusive design principles.

References

Advance HE (n.d.) *Athena Swan*. Available at: https://www.advance-he.ac.uk/equality-charters/international-charters/athena-swan-ireland [Accessed: 13 April 2023].

Anderson, N., Lankshear, C., Timms, C. & Courtney, L. (2008) 'Because it's boring, irrelevant and I don't like computers': Why high school girls avoid professionally-oriented ICT subjects. *Computers and Education*, 50(4), 1304–1318.

Ashcraft, C., Mclain, B. & Eger, E. (2016) *Women in tech: The facts*. Boulder, CO. Available at: https://www.ncwit.org/sites/default/files/resources/womenintech_facts_fullreport_05132016.pdf [Accessed: 13 April 2023].

Augustsson, D. (2021) Expansive learning in a change laboratory intervention for teachers. *Journal of Educational Change*, 22(4), 475–499. [Accessed: 13 April 2023].

Bal, A., Afacan, K. & Cakir, H.I. (2019) Transforming Schools from the Ground-Up with Local Stakeholders: Implementing Learning Lab for Inclusion and Systemic Transformation at a Middle School. *Interchange*, 50(3), 359–387. Springer Netherlands.

Barker, L.J. & Aspray, W. (2013) The State of Research on Girls and IT. In: *Women and Information Technology*. [Online]. Available at: doi:10.7551/mitpress/9780262033459.003.0001

Beason, K., Fenwick, J.B. & Norris, C. (2020) *Introducing Middle School Students to Computational Thinking with the CS First Curriculum*. In: Association for Computing Machinery, 2020. New York, NY, USA: Association for Computing Machinery. Available at: doi:10.1145/3374135.3385264

Bjorn, P., Menendez, M. & Borsotti, V. (2023) *Diversity in Computer Science: Design Artefacts for Equity and Inclusion*. [Online]. Available at: doi:10.1007/978-3-031-13314-5

Blickenstaff, J.C. (2005) Women and science careers: Leaky pipeline or gender filter? *Gender and Education*, 17(4), 369–386.

Bligh, B. (2024) *The Change Laboratory as a Collaborative Approach to Designing Tools and Activity Systems for Learning*. [Online]. Available at: doi:10.4324/9781003429821-20

Bligh, B. & Flood, M. (2015) *The Change Laboratory in Higher Education: Research-intervention using activity theory. In J. Huisman, & M. Tight (Eds.), Theory and Method in Higher Education Research (volume 1, pp. 141-168). Emerald.*

Bligh, B. & Flood, M. (2017) Activity theory in empirical higher education research: choices, uses and values. *Tertiary Education and Management*, 23(2), 125–152. Routledge.

Blunden, A. (2010) *An Interdisciplinary Theory of Activity*. Leiden: Brill.

Buffum, P.S., Boyer, K.E., Wiebe, E.N., Mott, B.W. & Lester, J.C. (2015) Mind the gap: Improving gender equity in game-based learning environments with learning companions. *Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics)*, 9112, 64–73.

Cakir, H.I., Bal, A., Engeström, Y. & Sannino, A. (2022) Contradictions as an entry into inclusive systemic design: Addressing racial disparities in the discipline at an urban middle school. *Learning, Culture and Social Interaction*, 35(May), 100641.

Cateté, V., Wassell, K. & Barnes, T. (2014) Use and development of entertainment technologies in after school STEM program. *SIGCSE 2014 - Proceedings of the 45th ACM Technical Symposium on Computer Science Education*, 163–168.

Chen, Y., Chen, Z., Gumidyala, S., Koures, A., Lee, S., Msekela, J., Remash, H., Schoenle, N., Albright, S.D. & Rebelsky, S.A. (2019) A middle-school code camp emphasizing digital humanities. *SIGCSE 2019 - Proceedings of the 50th ACM Technical Symposium on Computer Science Education*, 351–357.

Cheryan, S., Master, A. & Meltzoff, A.N. (2015) Cultural stereotypes as gatekeepers: Increasing girls' interest in computer science and engineering by diversifying stereotypes. *Frontiers in Psychology*, 6(FEB), 1–8.

Cheryan, S., Plaut, V.C., Handron, C. & Hudson, L. (2013) The Stereotypical Computer Scientist: Gendered Media Representations as a Barrier to Inclusion for Women. *Sex Roles*, 69(1–2), 58–71.

Cheryan, S., Ziegler, S.A., Montoya, A.K. & Jiang, L. (2017) Why are some STEM fields more gender balanced than others? *Psychological Bulletin*, 143(1), 1–35. American Psychological Association Inc.

Cleary, A., Vandenbergh, L. & Peterson, J. (2015) Reactive game engine programming for STEM outreach. *SIGCSE 2015 - Proceedings of the 46th ACM Technical Symposium on Computer Science Education*, 628–632.

Craig, M. & Horton, D. (2009) Gr8 designs for Gr8 girls: a middle-school program and its evaluation. *SIGCSE Bulletin Inroads*, 41(1), 221–225.

Daniels, H. (2008) *Vygotsky and research*. Routledge.

Denner, J., Werner, L., Bean, S. & Campe, S. (2005) The girls creating games program: Strategies for engaging middle-school girls in information technology. *Frontiers*, 26(1), 90–98.

Denner, J., Werner, L., Campe, S. & Ortiz, E. (2014) Pair programming: Under what conditions is it advantageous for middle school students? *Journal of Research on Technology in Education*, 46(3), 277–296.

Denner, J., Werner, L., Martinez, J. & Bean, S. (2012) Computing goals, values, and expectations: Results from an after-school program for girls. *Journal of Women and Minorities in Science and Engineering*, 18(3), 199–213.

Denning, T., Lerner, A., Shostack, A. & Kohno, T. (2013) Control-Alt-Hack: The design and evaluation of a card game for computer security awareness and education. *Proceedings of the ACM Conference on Computer and Communications Security*, 915–928.

Department of Education and Skills (2017) *STEM Education Policy Statement 2017–2026*. Available at: https://assets.gov.ie/static/documents/stem-education-policy-statement-2017-2026.pdf

Eidelman, L., Hazzan, O., Lapidot, T., Matias, Y., Raijman, D. & Segalov, M. (2011) Mind the (Gender) gap: Can a two-hour visit to a hi-tech company change perceptions about computer science? *ACM Inroads*, 2(3), 64–70.

Engels, F. (1976) *Anti-Dühring*. Progress Publishers.

Engeström, Y. (1987) *Learning by Expanding: An Activity Theoretical Approach to*

Developmental Research. Helsinki, Finland: Orienta-Konsultit.

Engeström, Y. (1993) Developmental studies of work as a testbench of activity theory: The case of primary care medical practice. In: Lave, J. & Chaiklin, S. (eds.) *Understanding Practice: Perspectives on Activity and Context* Learning in Doing: Social, Cognitive and Computational Perspectives. [Online]. Cambridge: Cambridge University Press. Available at: doi:DOI: 10.1017/CBO9780511625510.004

Engeström, Y. (1999) Innovative learning in work teams: Analyzing cycles of knowledge creation in practice. In: Punamäki, R.-L., Miettinen, R. & Engeström, Y. (eds.) *Perspectives on Activity Theory* Learning in Doing: Social, Cognitive and Computational Perspectives. [Online]. Cambridge: Cambridge University Press. Available at: doi:DOI: 10.1017/CBO9780511812774.025

Engeström, Y. (2000) Activity theory as a framework for analyzing and redesigning. *Ergonomics*, 43(7), 960–974.

Engeström, Y. (2001) Expansive Learning at Work: Toward an activity theoretical reconceptualization. *Journal of Education and Work*, 14(1), 133–156.

Engeström, Y. (2008) From teams to knots. In: *Activity-Theoretical Studies of Collaboration and Learning at Work*. [Online]. Available at: doi:10.1017/CBO9780511619847

Engeström, Y. (2014) *Learning by Expanding: An Activity-Theoretical Approach to Developmental Research*. 2nd ed. [Online]. Cambridge: Cambridge University Press. Available at: doi:DOI: 10.1017/CBO9781139814744

Engeström, Y. (ed.) (2016a) From design experiments to formative interventions. In: *Studies in Expansive Learning: Learning What Is Not Yet There*. [Online]. Cambridge: Cambridge University Press. Available at: doi:DOI: 10.1017/CBO9781316225363.011

Engeström, Y. (2016b) *Studies in Expansive Learning*. [Online]. Cambridge: Cambridge University Press. Available at: doi:10.1017/CBO9781316225363

Engeström, Y., Engeström, R. & Kerosuo, H. (2003) The Discursive Construction of Collaborative Care. *Applied Linguistics*, 24(3), 286-315+419.

Engeström, Y., Rantavuori, J. & Kerosuo, H. (2013) Expansive Learning in a Library: Actions, Cycles and Deviations from Instructional Intentions. *Vocations and Learning*, 6(1), 81–106.

Engeström, Y. & Sannino, A. (2010) Studies of expansive learning: Foundations, findings and future challenges. *Educational Research Review*, 5(1), 1–24.

Engeström, Y. & Sannino, A. (2011) Discursive manifestations of contradictions in organizational change efforts: A methodological framework. *Journal of Organizational Change Management*, 24(3), 368–387.

Engeström, Y. & Sannino, A. (2021) From mediated actions to heterogenous coalitions: four generations of activity-theoretical studies of work and learning. *Mind, Culture, and Activity*, 28(1), 4–23. Routledge.

EUGAIN (n.d.) *COST Action CA19122*. Available at: https://eugain.eu/ [Accessed: 13 April 2023].

Fisher, A. & Margolis, J. (2002) Unlocking the clubhouse. *ACM SIGCSE Bulletin*, 34(2), 79–83.

French, J. & Crouse, H. (2018) Using early intervention to increase female interest in computing sciences. *Journal of Computing Sciences in Colleges*, 34(2), 133–140.

Galuppo, L., Kajamaa, A., Ivaldi, S. & Scaratti, G. (2019) Translating sustainability into action: A management challenge in FabLabs. *Sustainability (Switzerland)*, 11(6), 1–13.

Gannod, G.C., Burge, J.E., McIe, V., Doyle, M. & Davis, K.C. (2015) Increasing awareness of computer science in high school girls. *Proceedings - Frontiers in Education Conference, FIE*, 2015-Febru(February), 1–8. IEEE.

Garrett, B. & Nelkon, C. (2024) The Morecambe Bay Curriculum: Bringing about culture change through education. In: Key Cities Innovation Network *Civic partners in net zero: Innovative approaches to universities working with their places to achieve net zero targets*. [Online]. Key Cities Innovation Network. Available at: https://keycities.uk/wp-content/uploads/2024/04/KCIN-UI1-CIVIC-PARTNERS-IN-NET-ZERO-ONLINE.pdf

Goode, J., Chapman, G. & Margolis, J. (2012) Beyond curriculum: The exploring Computer Science program. *ACM Inroads*, 3(2), 47–53.

Goode, J., Margolis, J. & Chapman, G. (2014) Curriculum is not enough: The educational theory and research foundation of the Exploring Computer Science professional development model. *SIGCSE 2014 - Proceedings of the 45th ACM Technical Symposium on Computer Science Education*, 493–498.

Google (2024) *2024 Google Diversity Annual Report: Driving innovation, bridging gaps*. Available at: https://belonging.google/diversity-annual-report/2024/

Gottipati, S. & Shankararaman, V. (2018) Using Gamification in Outreach Camps: Experience from an IS Program. *Proceedings - Frontiers in Education Conference, FIE*, 2018-Octob, 1–8. IEEE.

Gottipati, S., Shankararaman, V. & Megargel, A. (2018) Applyping design thinking to student outreach projects: Experiences from an information systems school. *2018 SIGED International Conference on Information Systems Education and Research*.

Gürer, D. & Camp, T. (2002) An ACM-W literature review on women in computing. *ACM SIGCSE Bulletin*, 34(2), 121–127.

Haapasaari, A., Engeström, Y. & Kerosuo, H. (2016) The emergence of learners' transformative agency in a Change Laboratory intervention. *Journal of Education and Work*, 29(2), 232–262. Routledge.

Hasted, C. (2019) *Humanities doctoral education for a relational future: a Change Laboratory research intervention*. [Doctoral Thesis, Lancaster University]. Lancaster University. https://doi.org/10.17635/lancaster/thesis/650

Higher Education Authority (2022) *National Access Plan: A strategic action plan for equity of access, participation and success in higher education 2022-2028*. Dublin.

Higher Education Authority (HEA) (2022) *Higher Education Institutional Gender Review*. Higher Education Authority. Available at: https://hea.ie

Hopwood, N. (2024) Twenty-five years of change laboratories in schools: a critical and formative review. *Educational Action Research*, 00(00), 1–28. Routledge.

Hopwood, N., Pressick-Kilborn, K., Pant, B.P., Dhungana, P., Shrestha, D., Shahi, R., Dorji W, S., Wangchuk, T.K., Wangchuk, T., Zangmo, T. & Choden, S. (2024a) School-University Partnerships on the Edge of Possibility: Expansive Learning and Practice Transformation Across Australia, Nepal, and Bhutan. In: Springer Nature Singapore *Creating, Sustaining, and Enhancing Purposeful School-University Partnerships: Building Connections Across Diverse Educational Systems*. [Online]. Singapore: Springer Nature Singapore. Available at: doi:10.1007/978-981-99-8838-9_10

Hopwood, N., Zeivots, S., Wardak, D. & Cram, A. (2024b) Co-design practice in higher education: practice theory insights into collaborative curriculum development. *Higher Education Research and Development*, 1–15.

Huggard, M. & Mc Goldrick, C. (2006) Incentivising students to pursue Computer Science Programmes. *Proceedings - Frontiers in Education Conference, FIE*, 3–8. IEEE.

Hulsey, C., Pence, T.B. & Hodges, L.F. (2014) Camp CyberGirls: Using a virtual world to introduce computing concepts to middle school girls. *SIGCSE 2014 - Proceedings of the 45th ACM Technical Symposium on Computer Science Education*, 331–336.

Ilyenkov, E. V (1977) *Dialectical Logic; Essays on its History and Theory*.

Issroff, K. & Scanlon, E. (2002) Using technology in higher education: An activity theory perspective. *Journal of Computer Assisted Learning*, 18(1), 77–83.

Isvik, A., Catete, V. & Barnes, T. (2020) FLAMES: A Socially Relevant Computing Summer Internship for High School Students. *2020 Research on Equity and Sustained Participation in Engineering, Computing, and Technology, RESPECT 2020 - Proceedings*, 2020–2023.

Jamshidi, F., Bigonah, M. & Marghitu, D. (2024) Striking a Chord through a Mixed-Methods Study of Music-Based Learning to Leverage Music and Creativity to Bridge the Gender Gap in Computer Science. *SIGCSE 2024 - Proceedings of the 55th ACM Technical Symposium on Computer Science Education*, 2, 1694–1695.

Joshi, A. & Jain, A. (2018) Reflecting on the Impact of a Course on Inclusive Strategies for Teaching Computer Science. *Proceedings - Frontiers in Education Conference, FIE*, 2018-Octob. IEEE.

Kaval, S., Reddy, M. & O'Neill, A. (2024) Computer Science Kickstart: An Innovative Bootcamp to Ignite Passion in First-Year Female-Identifying University Students. *SIGCSE 2024 - Proceedings of the 55th ACM Technical Symposium on Computer Science Education*, 2, 1700–1701.

Kim, J., Liao, Y.-C., Guo, M., Karlin, M. & Leftwich, A. (2023) *Why should we be Integrating Computer Science into the Elementary Curriculum?: Computer Science Teachers' Perceptions and Practices*. [Online]. Available at: doi:10.1145/3545947.3576370

Lakanen, A.J. & Kärkkäinen, T. (2019) Identifying pathways to computer science: The long-term impact of short-term game programming outreach interventions. *ACM Transactions on Computing Education*, 19(3), 1–30.

Lang, C., Fisher, J., Craig, A. & Forgasz, H. (2015) Outreach programmes to attract girls into computing: how the best laid plans can sometimes fail. *Computer Science Education*, 25(3), 257–275. Routledge.

Lang, C., Fisher, J., Craig, A. & Forgasz, H. (2020) Computing, girls and education: What we need to know to change how girls think about information technology. *Australasian Journal of Information Systems*, 24, 1–31.

Lau, W.W.Y., Ngai, G., Chan, S.C.F. & Cheung, J.C.Y. (2009) Learning programming through fashion and design: A pilot summer course in wearable computing for middle school students. *SIGCSE Bulletin Inroads*, 41(1), 504–508.

Lawlor, G., Byrne, P. & Tangney, B. (2020) 'CodePlus'-Measuring short-term efficacy in a non-formal, all-female CS outreach programme. *ACM Transactions on Computing Education*, 20(4).

Leont'ev, A.N. (1978) *Activity, Consciousness, and Personality*. Prentice-Hall Englewood Cliffs, Nj.

Lyon, L.A. & Green, E. (2021) Coding Boot Camps: Enabling Women to Enter Computing Professions. *ACM Transactions on Computing Education*, 21(2), 1–30.

Margolis, J. & Fisher, A. (2003) *Unlocking The Clubhouse: Women in Computing*. Cambridge, Massachusetts: The MIT Press, Cambridge, Massachusetts.

Marx, K. (1976) *Karl Marx, Frederick Engels: Collected Works. Volume 5 (1845-1847)*. London: Lawrence & Wishart.

Miles, R. (2022) The insider Change Laboratory in practice. *Studies in Technology Enhanced Learning*, 3(1).

Mladenović, S., Krpan, D. & Mladenovic, M. (2016) Using games to help novices embrace programming: From elementary to higher education. *International Journal of Engineering Education*, 32(1), 521–531.

Moffitt, P. (2018) *Transformative Agency For The Collaborative And Future-Oriented Redesign Of Activity In Military Higher Education; Empowering Participants To Change Their Boundary-Crossing Technology Enhanced Learning*. Lancaster University.

Moffitt, P. & Bligh, B. (2021) Video and the pedagogy of expansive learning: Insights from a research-intervention in engineering education. *Video Pedagogy: Theory and Practice*, 123–145. Springer.

Nuttall, J. (2022) Formative interventions and the ethics of double stimulation for transformative agency in professional practice. *Pedagogy, Culture and Society*, 30(1), 111–128.

OECD (2021) *OECD Digital Education Outlook 2021 | OECD*. [Online]. Available at: https://www.oecd.org/en/publications/oecd-digital-education-outlook-2021_589b283f-en.html

Ollman, B. (2003) *Dance of the Dialectic*. Urbana, IL: University of Illinois Press.

Page, S. (2007) The Difference: How the Power of Diversity Creates Better Groups, Firms, Schools, and Societies. *The Difference: How the Power of Diversity Creates Better Groups, Firms, Schools, and Societies (New Edition)*.

Redmond, F. (2022) *With a Rise in Computing Disciplines Comes a Greater Variety of Academic Choices in Higher Education.* In Koli Calling '22: 22nd Koli Calling International Conference on Computing Education Research (Koli 2022). Association for Computing Machinery, New York, NY, USA, Article 5, 1–11. https://doi.org/10.1145/3564721.3565946

Redmond, F. (2023) Project management of an online Change Laboratory using Notion. *Bureau de Change Laboratory*, 1–11.

Roscoe, J.F., Fearn, S. & Posey, E. (2014) Teaching computational thinking by playing games and building robots. *Proceedings - 2014 International Conference on Interactive Technologies and Games, iTAG 2014*, (December 2014), 9–12.

Rosson, M.B., Sinha, H., Hansford, T. & Mahar, J. (2010) Offering early success experiences in software construction: Experiences teaching dynamic website development to high school girls. *Proceedings - 10th IEEE International Conference on Advanced Learning Technologies, ICALT 2010*, 458–460. IEEE.

Royal Society (2017) *After the reboot : computing education in UK schools Contents*.

Şahin Timar, Z. & Mısırlı, Ö. (2023) Effective Strategies for Encouraging Girls in Informatics. *Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics)*, 14021 LNCS, 377–392.

Sanders, E.B.-N. & Stappers, P.J. (2008) Co-creation and the new landscapes of design. *CoDesign*, 4(1), 5–18. Taylor & Francis.

Sannino, A. (2010) Teachers' talk of experiencing: Conflict, resistance and agency. *Teaching and Teacher Education*, 26(4), 838–844. Elsevier Ltd.

Sannino, A. (2011) Activity theory as an activist and interventionist theory. *Theory & Psychology*, 21(5), 571–597.

Sannino, A. (2015) The emergence of transformative agency and double stimulation: Activity-based studies in the Vygotskian tradition. *Learning, Culture and Social Interaction*, 4, 1–3. Elsevier Ltd.

Sannino, A., Engeström, Y. & Lemos, M. (2016) Formative Interventions for Expansive Learning and Transformative Agency. *Journal of the Learning Sciences*, 25(4), 599–633.

Sauppé, A., Szafir, D., Huang, C.-M. & Mutlu, B. (2015) *From 9 to 90: Engaging Learners of All Ages. In Proceedings of the 46th ACM Technical Symposium on Computer Science Education*

(SIGCSE '15). Association for Computing Machinery, New York, NY, USA, 575–580. https://doi.org/10.1145/2676723.2677248

Sax, L.J., Kanny, M.A., Riggers-Piehl, T.A., Whang, H. & Paulson, L.N. (2015) “But I’m Not Good at Math”: The Changing Salience of Mathematical Self-Concept in Shaping Women’s and Men’s STEM Aspirations. In: Springer Netherlands *Research in Higher Education*. [Online]. Springer Netherlands. Available at: doi:10.1007/s11162-015-9375-x

Scahill, J. (2021) *Concept development and transformative agency in the forging of a Campus Sustainability Statement : Insights from a Change Laboratory research-intervention*. (July), 1–289.

Scahill, J. & Bligh, B. (2022) Developing Stakeholder Agency in Higher Education Sustainability Initiatives. *The Wiley Handbook of Sustainability in Higher Education Learning and Teaching*, 99–131.

Scanlon, E. & Issroff, K. (2005) Activity Theory and Higher Education: Evaluating learning technologies. *Journal of Computer Assisted Learning*, 21(6), 430–439.

Scott, A., McAlear, F., Martin, A. & Koshy, S. (2017) Broadening participation in computing: Examining experiences of girls of color. *ACM Inroads*, 8(4), 48–52.

Sentance, S. & Csizmadia, A. (2017) Computing in the curriculum: Challenges and strategies from a teacher’s perspective. *Education and Information Technologies*, 22(2), 469–495. Education and Information Technologies.

Serussi, S. & Divitini, M. (2017) GIRLS AND COMPUTING IN LOWER SECONDARY EDUCATION: The surprisingly unsurprising results of a Norwegian exploratory study. *Proceedings of NOKOBIT - Norsk konferanse for organisasjoners bruk av informasjonsteknologi*, 25(1).

Settle, A., Franke, B., Hansen, R., Spaltro, F., Jurisson, C., Rennert-May, C. & Wildeman, B. (2012) Infusing computational thinking into the middle- and high-school curriculum. *Annual Conference on Innovation and Technology in Computer Science Education, ITiCSE*, 22–27.

Sharma, K., Torrado, J.C., Gómez, J. & Jaccheri, L. (2021) Improving girls’ perception of computer science as a viable career option through game playing and design: Lessons from a systematic literature review. *Entertainment Computing*, 36(April 2020).

Spante, M., Moffitt, P., Bligh, B., Lemonie, Y., Matsmoto, R., Munday, D., Nodder, J., Querol, M.P. & Redmond, F. (2023) Why do an online Change Laboratory? *Bureau de Change Laboratory*, 1–14.

Spinuzzi, C. (2005) The Methodology of Participatory Design. *Technical Communication*, 52, 163–174.

Trowler, P.R. (2016) *Doing Doctoral Research into Higher Education… and getting it right.* CreateSpace Independent Publishing Platform.

UNESCO (2017) *Cracking the code: girls' and women's education in science, technology, engineering and mathematics (STEM) - UNESCO Digital Library*. Available at: https://unesdoc.unesco.org/ark:/48223/pf0000253479

UNESCO (2023) *New factsheet highlights gender disparities in innovation and technology*. UNESCO. Available at: https://www.unesco.org/en/articles/international-womens-day-new-factsheet-highlights-gender-disparities-innovation-and-technology

United Nations (2015) *Transforming our world: The 2030 Agenda for Sustainable Development*. United Nations. Available at: https://sdgs.un.org/goals

Veron, T., Iles, T., Khan Ashar, A.A. & Liu, J. (2023) Computer Science (CS) Day for Middle School Students. *Proceedings - Frontiers in Education Conference, FIE*. IEEE.

Virkkunen, J. (2006) Dilemmas in building shared transformative agency. *Activites*, 03(1).

Virkkunen, J. & Newnham, D.S. (2013) *The Change Laboratory: A Tool for Collaborative Development of Work and Education*. Rotterdam: Sense Publishers.

Voogt, J.M., Pieters, J.M. & Handelzalts, A. (2016) Teacher collaboration in curriculum design teams: effects, mechanisms, and conditions. *Educational Research and Evaluation*, 22(3–4), 121–140. Taylor & Francis.

Vygotsky, L.S. (1978) *Mind in Society* Cole, M., Jolm-Steiner, V., Scribner, S. & Souberman, E. (eds.). [Online]. Harvard University Press. Available at: doi:10.2307/j.ctvjf9vz4

Wang, M. Te & Degol, J.L. (2017) Gender Gap in Science, Technology, Engineering, and Mathematics (STEM): Current Knowledge, Implications for Practice, Policy, and Future Directions. *Educational Psychology Review*, 29(1), 119–140. Educational Psychology Review.

Webb, D.C., Repenning, A. & Koh, K.H. (2012) Toward an emergent theory of broadening participation in computer science education. *SIGCSE'12 - Proceedings of the 43rd ACM Technical Symposium on Computer Science Education*, 173–178.

Yates, J. & Plagnol, A.C. (2022) Female computer science students: A qualitative exploration of women's experiences studying computer science at university in the UK. *Education and Information Technologies*, 27(3), 3079–3105. Springer US.

Zahedi, M., Tessier, V. & Hawey, D. (2017) Understanding Collaborative Design Through Activity Theory. *Design Journal*, 20(sup1), S4611–S4620. Routledge.