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Abstract:

Much of the existing literature on space and practice originates from the fields of human geography, urban sociology and architecture. Seminal contributors to these fields including: Tuan (Tuan 1977), Edwards (Edwards and Usher 2003), Dourish (Harrison and Dourish 1996), and Hall (Hall 1990), and they provide useful terminology and applications for defining space and the interactions that occur within them.

For many of these writers, a 'space' is just a physical volume that provides the opportunity for human interactions to occur, whereas a 'place' is the lived-experience of those human interactions - that is, 'places' are 'spaces' that are invested with meaning, identity and practice.

Despite the large quantity of literature from other fields on the study of space, it has received limited attention and application in the fields of Higher Education and Computing Education. When research on place has been conducted, it is generally concerned with the physical design and perception of spaces. Addressing this research gap and obtaining a deeper understanding of students' use of physical and virtual spaces, will give us a richer picture of their engagement during their academic study. Understanding why students go to certain places rather than others, the practice that happens in these places and how spaces become associated with certain types of culture and activities, will better inform our pedagogical approach to teaching computing.

A CARTOGRAPHY OF PRACTICE

A THESIS SUBMITTED TO
THE UNIVERSITY OF KENT
IN THE SUBJECT OF COMPUTER SCIENCE
FOR THE DEGREE
OF PHD.

BY

DANIEL KNOX

SEPTEMBER 2017

“We often assume that learning has a beginning and an end; that it is best separated from the rest of our activities; and that it is the result of teaching.” (Wenger 2000)

Acknowledgements

To list everyone who has supported and shaped my education would be an impossible task, there are simply too many people who have helped me get to the place I am now. To all of you: thank you.

My parents, John and Karen, have always stood behind me and have ensured that I can always pursue my dreams. My thanks especially to my father for spending many hours reading my work, looking for spelling and grammar mistakes to red-line. To both of you: thank you and my love as always.

I would have not been able to complete this thesis without the supervision provided by my supervisor, Sally Fincher. Sally has helped me to develop a countless array of skills and experience many once-in-a-lifetime opportunities. Although I still struggle to use a semi-colon appropriately, thanks to Sally my writing today compared with four years ago is unrecognisable. Sally: Thank you for saying `yes' right at the beginning, providing me with the skills to make it through and setting the stage for a possible future career in research.

And lastly, thanks to my loving wife, Jutta. She has stood by me throughout my journey, even during its darker days, and helped me through when I have needed it the most. Jutta: I love you always.

Abstract and Research Justification

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Chapter 1 - Introduction

For this chapter, we will first introduce the pilot study that motivated the thesis of this research; the purpose of the pilot study was to explore the notion “authentic practice” in computer science education. From this pilot study, we identify three important themes: space, place and practice, and conduct a literature review of them. Informed by this literature we conclude the introduction chapter by presenting our thesis and the research questions.

1.1 Pilot study

My own learning trajectory motivated my interest in exploring the notion that an authentic practice of computing increases students’ motivation to pursue and maintain the study of computer science at higher education. By authentic practice, we mean that the tasks that students participate with are not artificially constructed problems; but instead, situated in a ‘real’ context. To examine opportunities for “authenticity” in students’ experience I undertook an exploratory study of two groups of students ages 17 - 18. At the time that this study was conducted, compulsory education in the UK was up to the age of 16. Following this year, students either apply to a college or a sixth form within a school for further study, or they leave full time education and enter the workplace. Those who choose further study, commonly do so for two additional years (ages 17 - 18) before leaving to enter the workplace or going to university to study a degree.

For this study, both groups of students were still working within a school, in a formal education setting.

The first group consisted of several students in a school who spent their free-time in a technicians' support room, two of the group were in their final year of study and were applying to university to study computer science. For this group of students, I spent one week within the Technicians' Room observing the student interactions with each other, the teachers and the support staff. At the end of the week of observation, I conducted a focus group interview with these students and a separate interview with the staff.

The second group consisted of apprentices from a local apprenticeship scheme who were working for a company that provided technical computer support and infrastructure management for schools in Kent. Instead of entering further education, these students had left formal education at the age of 16 to join this apprenticeship scheme and had no intention of studying computer science at university; instead, they had chosen to enter professional practice and to conduct their training on-the-job. However, each week for one day these apprentices would come together and attend a local college in order to study for a qualification on computer networking. For this group of students, I went to the college and attended one of their days of study; during a break, I conducted a focus group interview with them.

Ethical approval was obtained from the Sciences Research Ethics Advisory Group (University of Kent) and the data collected from each of these interviews and observations have been collated to produce the following two vignettes. All names used in this thesis have been replaced with pseudonyms to protect the anonymity of the individuals who participated.

Vignette 1 -- The Technicians' Room



Figure 1: The Technicians' Room

The Technicians' Room is a small, but long room located at a single-sex school in Kent, England. On the left-hand side of it are rack cabinets that contain the servers and network switches which provide the backbone services to the school's computers; the constant whir of this equipment creates a low volume humming in the room. On the right-hand side a desk runs the length of the room. Several Linux computers, with local administrator access, sit here and are wired into a spare network switch. A technician usually sits at the end of this desk with his laptop, but he is currently out providing technical support. Cabinets hang above this desk and contain a range of spare computer hardware: graphics cards, memory, processors, motherboards and various networking equipment. At the far end of the room, another desk (adjacent to the long one) crosses the width of the room. One of the members of staff regularly sits there with their laptop.

Richard (aged 15) is developing a tile game in C++ on one of the desktop computers. He had attempted and completed a similar game before, but he had never felt happy

about how it was written. Another student, Jake (aged 18), leans over Richard's shoulder.

Jake: *"Why are you doing it in XML?"*

Richard: *"Because I want an easy way to store the configurations."*

Jake: *[Ponders this for a moment and then points at Richard's screen]"Ah OK, well you haven't got a root node there and you need that."*

Richard: *[Looks at where Jake is pointing and inserts a new line of text] "Oh yeah, I had missed that."*

This kind of interaction, between Jake and Richard, is not unusual; both students regularly help each other with their programming. A little while later, Richard takes a break from programming his tile game. He turns to his computing teacher, Paul, who is also the 'Director of ICT' at the school.

Richard: *"The clocks on the computers down in Business Studies are really out."*

Paul: *"If you like, you can look into that. The clients should be syncing their time on boot."*

Richard appears keen and asks Paul a number of questions about the clients' boot procedure. Whilst responding to these questions, Paul looks through the clients' scripts and locates one; he motions at a section of it.

Paul: *"This is the script that handles the clients' booting and they should query the main server for the time around here. It could be a simple problem with this variable."*

[The variable declares the server hostname of the time server in the school]

Richard: *"If the client doesn't know the server's hostname?"*

Paul: *"Yes. That is set elsewhere, but it might be causing the problem."*

Richard: *“OK. I will look into that, I can do it in my ICT class later.”*

It later transpired that the problem was related to a variable being set incorrectly and that Richard had identified a ‘bug’ in the school’s custom Linux distribution. Richard’s identification of a software bug and the earlier ‘pair programming’ example between him and Jake, are not isolated occurrences; the two students regularly work with each other and help develop parts of the school’s Linux distribution. Furthermore, Richard and Jake are not the only students who spend their free-time in this room; three other students regularly come and use the equipment in the cabinets, the Linux computers and configure the spare network equipment. The three other students are:

- Gareth (aged 18) - Studies A-Level computing and is best friends with Jake. Both Gareth and Jake have applied to the same university to study computer science.
- Keith (aged 15) - Studies GCSE ICT.
- Archie (aged 14) - Is a relative ‘new-comer’ to the room and is currently studying ICT in the lower years of the school.

For these students, the Technicians’ Room facilitates immersion in a kind of computing that is relevant to them; here they can talk about computer games, program and do other ‘computery stuff’. It is important to note that the activities the students undertake here are of their own choosing; the Director of ICT has not created a curriculum or any formal learning programme. Furthermore, the students choose to come to the room - they are not required to come here and there are other computer rooms that are open to all students (as long as they are completing

schoolwork and only if a teacher is able to supervise); therefore the Technicians' Room is important to the students.

Vignette 2 -- The Apprenticeship Scheme

In 2010, 'new-build' schools in the South-East of England had their computer systems and technical support managed by an external company. This company is part of a scheme known as 'Building Schools for the Future' (BSF). Each BSF school has an on-site engineer to whom, typically, one or more apprentices are assigned. The apprenticeship lasts for one year and at the end of the apprenticeship many of the apprentices continue working for the company as engineers. There are ten apprentices in the scheme in Kent; eight are half way through and two are nearly finished.

To do their work, the apprentices and engineers have administrator access on the schools' desktop computers; what they can do on these machines is defined by policies set out by the BSF scheme and the company. These same policies also define how the apprentices should interact with pupils and teachers of the school. In an interview, the apprentices described their experience of the apprenticeship.

Neil: *"I think at first, you're a bit not too sure what to do, but then obviously you get used to it, like anything else. And then they sort of give you leeway and you go off and do your own thing, start doing stuff on your own and that."*

Alan: *"Sort of tell you you've got to do this, and then eventually you're sort of, 'oh, I've got to do it myself', so they're waiting for something to do."*

Jamie: *"The jobs come in and then you just talk to your manager, 'oh, I'll go and do this' and then you do it, you close the call and that's it. He goes off and does something else. It's working together really, once you get used to it."*

Their experience of the scheme is similar to what we would expect from a traditional trade apprenticeship; apprentices are assigned to someone more experienced and start by observing this person at work. As the apprentices' confidence and experience develops, by completing smaller jobs under the guidance of the experienced other, they begin to take on more responsibilities and become more independent. However, unlike a traditional apprenticeship, once a week the apprentices leave the professional environment and come together to attend a full day in an academic environment, a local college, to study for a network and computer systems management qualification (BTEC Networking). The class at college is comprised only of students from the apprenticeship scheme.

During the interview (at the college) the students spoke about their experience of this formal education in comparison with their apprenticeship within the schools.

Alan: "I don't actually think it's that good a method of learning, because you just read it for, like, an hour. Write it down in your own words, and then forget about it. Like, the next week, what you've done? Sort of just writing it, some people don't learn from that. Write it down. Forget it. In the schools you learn loads more."

Neil: "Yeah you learn more about IT because you're fixing it. Sitting in the classrooms typing it all gets boring."

Alan: "But then again, we learn stuff here that we never would use at work."

Neil: "Yeah. Which is, you know, pointless."

Jamie: "Obviously, we're not going to gain more knowledge on that, because we're hands on and we're not doing it in work. We only do it once a week here."

The characteristics of the workplace environment and the day at a local college facilitate different kinds of practice for the apprentices. In the workplace, learning is situated and authentic; the knowledge and experience the apprentices develop is

directly related to the work that they do; furthermore, their skill is immediately validated when they attempt to resolve problems - their solutions either work or they don't.

In contrast, at the college, the apprentices find that in this environment their learning is abstract - the knowledge that the apprentices develop is decontextualized from the work that they do in the workplace; the tasks are pen and paper problems and they are not directly transferable. Because of this, the apprentices attribute a low value to the learning in this environment: "write it down in your own words, and then you forget about it".

Whilst the apprentices recognise that in the college environment they "learn stuff here that we never would use at work", it certainly does not "free" the apprentices in the same way as the Technicians' Room does for the school students. Instead, the college environment contributes differently to their learning and their sense of themselves as learners of computing.

Although there was some evidence of "authentic" practice, these exploratory studies of apprentices at college and with students in a school's Technicians' Room more strongly suggested that location was a significant factor, that *where* practice takes place is important. This informed my thesis that *space* is an important factor in affording student engagement and learning.

1.2 Space and Place

Researchers from a variety of disciplines have examined space. Reviewing their work helps provide a vocabulary for describing physical environments.

Tuan writes,

“ ‘Space’ and ‘place’ are familiar words denoting common experiences... These are unexceptional ways of speaking. Space and place are basic components of the lived world; we take them for granted. When we think about them, however, they assume unexpected meanings and raise questions we have not thought to ask” (Tuan 1977, p.3).

For Tuan, ‘space’ is an abstract term that describes a complex set of ideas and how it is divided up, valued, and measured, varies between different cultures; however, commonality does exist between cultures for its most basic characteristics. These basic characteristics are: “the posture and structure of the human body, and the relations (whether close or distant) between human beings.” (Tuan 1977, p.34).

When we describe space in this way, space exists purely as a dimensional construct: “I’m on top of a chair, by a computer, in a building called the Shed. My right arm is reaching out, holding a coffee cup”. Whilst this model of space may at first seem extremely basic, it is exactly how the world is viewed in the eyes of an infant, the few first years of a child’s development is dominated by the development of spatial awareness, with one of the earliest developmental stages being proprioception, the awareness of what exists as part of one’s own body and its position in relation to other objects in space.

However, when we think and describe space in everyday life, we rarely do so with such basic constructs. For adults, space is more complicated than just a set of proximal relations and spatial dimensions, “man, out of his intimate experience with

his body and with other people, organizes space so that it conforms with and caters to his biological needs and social relations... Body is “lived body” and space is humanly construed space” (Tuan 1977, p.35). Tuan uses an example of walking in a forest to illustrate this:

“What does it mean to be lost? I follow a path into the forest, stray from the path, and all of a sudden feel completely disoriented. Space is still organized in conformity with the sides of my body. There are regions to my front and back, to my right and left, but they are not geared to external reference points and hence are quite useless. Front and back regions suddenly feel arbitrary, since I have no better reason to go forward than to go back. Let a flickering light appear behind a distant clump of trees. I remain lost in the sense that I still do not know where I am in the forest, but space has dramatically regained its structure. As I move toward that goal, front and back, right and left have resumed meaning: I stride forward, am glad to have left dark space behind, and make sure that I do not veer to the right or left.” (Tuan 1977, p.36)

In this, the concept of space has become experiential to the individual and spatial dimensions become adorned with personal experience and emotion; as such, when human beings interact and utilise space, they impose their own personal schema upon it. This personal schema is formed by man’s personal experience of other spaces (e.g. I have had bad experiences walking down other alleyways), instinct (e.g. my eyesight is poor in the dark, so I am wary of dark spaces like that alleyway), and knowledge that has been shared by others (e.g. I’ve been told by others not to go down that alleyway).

Harrison and Dourish’s spatial model has a specific, but related, set of characteristics about space: 1) Relational orientation and reciprocity – a common orientation in the physical world. This is what lets us point to objects, or use spatial descriptions to establish reference. 2) Proximity and Action – in the everyday world, we act where

we are, understandings of proximity help us to relate people to activities and to each other. e.g. when we see people gathered around a meeting table, we understand something about their activity. 3) Partitioning – since actions and activity fall off with distance, so distance can be used to partition activities and the extent of interaction, 4) Presence and Awareness – the sense of other people’s presence and the ongoing awareness of activity allows us to structure our own activity, seamlessly integrating communication and collaboration ongoingly and unproblematically (Harrison and Dourish 1996).

Whist Harrison and Dourish’s definition of space shares many similarities with Tuan’s, it also emphasises the importance and influence that the presence of other human beings has on our individual perception of space. When we consider the history of mankind on Earth, what sets us apart from the other creatures is that we are less figures in the landscape and more shapers of the landscape. History is dominated by our crafting of the space around us as a way of communicating and influencing others – one wonders what potential invaders passing from Nubia into Egypt must have felt when they saw the two great temples of Ramesses II¹ rising out from the landscape?

How does ‘place’ relate to the characterisation of ‘space’? Nova writes that “Place is defined in anthropological terms as a space that has acquired meaning as a result of

¹ These two large temples consisted of four giant (20 metre) statues of Ramesses II, they were purposefully located close to the Nubian border in 1279-1213 BCE as a symbol of Egypt’s power in the region and to reinforce the status of its religion.

human activities” (Nova 2005, p.132). For Harrison and Dourish “physically, a place is a space which is invested with understandings of behavioural appropriateness, cultural expectations and so forth. We are located in ‘space’, but we act in ‘place’. Furthermore, ‘places’ are spaces that are valued” (Harrison and Dourish 1996). However, Erikson suggests that spaces do not automatically become ‘places’ from their outset and that time is required to build-up a history of shared experience:

“Closely associated with the fact that places have meanings, is that places often have activities associated with them. One way of capturing this is through the concept of ritual. Ritual is useful because it connects three important elements of human interaction: participants, repeated sets of actions, and artifacts or spaces” (Erickson 1993, p.402).

Therefore, by definition, ‘place’ is a purely human notion, it is made by people appropriating and living within a physical environment. It is also important to consider that because of this, individuals conceptualize places differently and as such, the same space can function as different places at different times, with no change to the physical environment or layout. Therefore, when we attempt to understand ‘place’, it crucial that we understand the space from the perspective of the person and attempt to account for the connection between humans, the physical environment, activities / practice and meanings (Relph 1976; Gustafson 2001; Ciolfi, Fitzpatrick and Bannon 2008) .

1.3 Space, Place and Practice

Now that we have a language for describing the physical environments that our students inhabit, we turn our focus to how we can apply these theories in practice.

An influential example of investigating practice and the role of space in affording it, is Julian Orr’s ethnographic study of technicians from the Xerox Corporation as they

went about their daily work supporting and repairing photocopier machines (Orr 1996).

Orr's motivation for conducting this study was that he believed existing research made assumptions about practice; he argued that a careful examination of practice *in situ* would reveal that actual work is different and more complex than we would normally expect. Orr based this belief from work conducted by Lucy Suchman, who claimed that cognitive phenomena have an essential relationship with collaboratively organized artefacts and actions (Suchman 2007). Orr's interpretation of this in his own work was that "[the study of work practice] must be done in the situation in which the work normally occurs, that is, work must be seen as situated in practice, in which the context is part of the activity" (Orr 1996, p.10).

For example, to do their work the photocopier technicians are provided with: manuals, sets of procedures to follow to locate the problem and guides about error codes. However, Orr observed the work done by the technicians in the field was often very different from the methods specified by their management in the machine documentation. This was because individual photocopier machines were idiosyncratic, with "new error codes appearing continuously" (Orr 1996, p.35); as such, the written procedures were often unable to address these unknown problems adequately. Much of the documentation also lacked realism about how technicians worked; for example, the documents would regularly suggest that changing electronic boards in the photocopier machines one-by-one was an appropriate method for resolving and diagnosing problems in a faulty machine. However, in

reality the technicians would never have all the boards with them at one time because the cost would be prohibitive.

By following the technicians around to the different clients, part drop-off points and meeting places, Orr was able to see how the technicians actually worked, not how their management believed they worked; observations revealed that the circulation of stories among the technicians was a key means by which they stayed informed of machine behaviour in the field. These stories occurred naturally, in diagnostic situations with the customer at the companies where the photocopier was in use and also in non-work situations, such as breaks.

One of the regular places where these stories were told was a local diner where the technicians would meet daily. During their chatting, the technicians would frequently include discussion on problematic machines and their interactions with people from the companies that they visited. These communal 'war stories' facilitated the sharing of knowledge between the technicians, by sharing their personal experiences of particular machines *in situ*. An important feature of these talks was that although the experience of the older technicians was commonly deferred to, any of the technicians could be the one to tell the story; for example, a new recruit used a story about a problematic machine to request help and advice from the others.

The diner where these stories were regularly told is similar to a kind of space that Oldenburg refers to as a 'Third Place' (Oldenburg 1998); a neutral ground where people gather and share conversation. Third Places are typified as unremarkable

structures that would likely not impress visitors, but for Oldenburg, are nonetheless important parts of neighbourhoods and cities because their characteristics afford comfortable, safe spaces where people can come and share conversation, no matter what their status.

Whilst Orr's study is a well-regarded example of work practice and the spaces that it occurs in, Mike Rose (Rose 2005) and Jan Nesper (Nesper 1994) both provide closer-to-home examples in education settings.

Mike Rose's Woodworking Shop

In his book 'The Mind at Work' (Rose 2005), Rose uses a naturalistic approach to provide an alternative lens on intelligence by observing the interplay of technical and verbal skills when people are planning and problem solving. As part of his research, Rose conducted an extended stay in a school's woodworking workshop to observe skill as it was developing. His account of the woodworking class of twenty-four students (taught by an experienced cabinetmaker, Mr. Devries) provides a number of examples of students learning their craft.

One example was Rose's observation of the interaction between two students, Ray and Billy, as they returned from the school library after taking some measurements for new doors for some storage cabinets:

“At some point, it seems, the librarian described to Ray the kind of doors she wanted ones with ventilating holes along the boom. As we walk, Ray is telling the story of their encounter... We talk a few minutes more, until we arrive at the classroom, Ray and Billy still discussing the doors and their function. Ray initiated the conversation to spark a laugh, but also, I think, to clarify things in the safe conversational space created through humour and with his

friend Billy, in motion, outside the library. The comic story becomes here a means to gain public consideration and assistance, to turn an event over in one's mind and to think it through in the presence of others" (Rose 2005, p.87).

This observation is similar to the example of the Xerox technicians: the telling of stories as a way to share knowledge and discuss problems. In this case, however, the story telling that occurs between Billy and Ray does not happen in a location like the diner, instead the interaction happens during a walk between two spaces (the library and the woodworking workshop).

This example is more reminiscent of Marc Augé's definition of 'Non-Places' (Augé 1995). Although Augé's seminal work approaches space from a more theoretical and abstract perspective, it is regularly drawn upon in architecture and geography as a way of describing certain kinds of spaces. Augé posits this about non-places:

"If a place can be defined as relational, historical and concerned with identity, then a space which cannot be defined as relational, or historical, or concerned with identify will be a non-place... it exists, but it does not contain any organic society" (Augé 1995, p.77).

Augé uses the example of an airport terminal to demonstrate the characteristics of a non-place (Augé 1995, p.101). For most people, an airport terminal is a space that is just a means to get somewhere else. Whilst we are transiting through the terminal, we have no other identity than that of a passenger; as an individual, we do not invest any time in developing a community or identity within that space.

It is important to recognize one obvious criticism that could be made about non-places (and places in general); in the case of the airport terminal, a person such as a baggage handler is unlikely to regard the space in the same way as the passenger. In

their case, they do invest time in developing a community and identity. Augé accepts this criticism and counters by stating that the same space can be different kinds of places, for different people and at different times (page 21).

The diner was a place that afforded the technicians to come and share their experience; its location, food and atmosphere encouraged the technicians to spend their time there with each other. Their own presence in the diner would also add to and reflect the atmosphere of the diner; as such, they are actively involved in the place's historical and relational development.

Rose's example of the students returning to the woodworking shop is the opposite of this; the students (Ray and Billy) are not engendering the corridor with their identity or a sense of community, it is just the physical path between two other spaces in the school (the library and the workshop); therefore, using Augé's definition, it is a non-place. However, although the corridor does not have the same significance that the diner had for the technicians, the corridor as a 'non-place' is still important as it afforded the discussion that Ray and Billy had during their passage through it.

Jan Nesor's Physics and Business Students

Jan Nesor's work directly considers the spatial issues that influence student practice. In his book 'Knowledge in Motion', Nesor observes and interviews students from two different degree programmes, Physics and Business Management (Nesor 1994). It is by arranging interviews that Nesor first considers the importance of space in influencing student practice; the physics students would always arrange the meeting to happen in the same space (the physics building),

whereas students from other programmes would arrange to meet in a large variety of different spaces.

During his interviews, Nespor finds the physics building a contradiction; the building was “the center of the academic and social universe of the students majoring in physics” (Nespor 1994, p.29), but spatially it was an “unwelcoming place”; with no space to sit, talk or write.

However, Nespor’s observations uncovered that many of the physics students would come to the building late at night to study and help each other complete their homework. This was because the difficulty of the physics programme was notorious and required substantial hours to be dedicated to academic study, working in the building late at night was a way that the students disciplined each other to the long hours that the programme required.

Nespor’s realization is important to our research because it demonstrates that the researcher needs not only to identify the spaces that students inhabit, but also be mindful that use of the same space can change at different times of the day; that is, they can have diurnal features. If Nespor had relied solely on the use of interviews (i.e. not participant observation), he may not have uncovered that the importance the physics students attributed to the physics building was partly because of their after-hours use.

In contrast to the physics programme, Nespor found that the business management students reserved substantial amounts of time for non-academic activity. Unlike the

physics building, the business building “reinforced the academic-non-academic divide by producing a public space that mimicked the spatial form of a corporate workplace” (Nespor 1994, p.111); for example, the furnishing and artwork in the building reflected corporate tastes in interior decoration. Nespor also observed that the wide landings of the building, the lobbies and the deep cushioned couches afforded spaces where the students would “chat between classes, read the newspaper and wait for each other” (Nespor 1994, p.111), a considerable contrast to the environment that the physics building portrayed. This corporate atmosphere within the academic environment had an important effect on the business management students; the way that they dressed and presented themselves also reflected a corporate setting.

1.4 Motivation for this research

Despite this quantity of literature from other fields on the study of space and place, it has received limited attention in computing and higher education. Where literature does exist in computing, such as Cheryan’s research on stereotyping and gender bias in computing classrooms (Cheryan, Master and Meltzoff 2015), Hamrin’s research exploring the notion of space in virtual collaborations (Hamrin and Persson 2010), and Clear’s research of distance, time and space in globally distributed development teams (Clear, Hussain and Macdonell 2012), it is predominately concerned with the physical affordances of spaces; that is, how the physical features of particular physical and virtual spaces influence different kinds of behaviour. In higher education, the literature that exists is primarily concerned with learning space evaluation models for use by university estates departments (Watson 2007; Pearshouse *et al.* 2009; Hunley and Schaller 2009; Roberts and Weaver 2007; NAO

1996), this considers space utilisation, but not its pedagogical role within specific disciplines. This lack of research within disciplines has been identified in a number of different papers (Temple 2008a; Temple 2008b; Edwards and Usher 2003; Jessop, Gubby and Smith 2012) with Montgomery summarising this state of affairs as “clearly the student voice is missing” (Montgomery 2008, p.131)

1.5 Purpose and Structure of this Research

As such, the purpose of this research is to study the use of space by computer science students throughout their academic study. Whilst we could evaluate and observe how lecture theatres and computer science classrooms influence student practice, our aim in this work is to look beyond these ‘obvious’ spaces. We regularly tell our students that our formal teaching just provides a skeleton to structure their learning and that most of their studies should happen away from the classroom, but where do students go? the library? their study bedrooms? and what do they do in those spaces? what happens when they get exhaust available local resources, do they go somewhere else?

1.6 Research Questions

My thesis is that “*space, place and practice* are important factors in affording student engagement and learning in computer science education”. To explore this thesis, several research questions will be addressed:

- 1. What spaces do computer students utilize outside of formal activity (lecture theatres, classrooms, etc.)?**

It is highly unlikely that every student utilises the same space to support their academic study; because of this, if we observe practice in a single space we would likely acquire a very narrow and impoverished view of their activities. As such, one of the first tasks of this research is to identify the different spaces that students use and their navigation between them. To do this, we present an instrument that allows us to identify physical spaces with academic importance to the students, for example cafés, corridors and virtual spaces, and gives access to spaces to which we might not normally be permitted to enter, for example, study bedrooms.

2. What are the practices that students engage with when they are studying computer science?

As Nicolini observes, when examining practice “if one is interested in real-life practices, they must be studied where they occur, in their natural setting, as bringing them into the laboratory is impossible” (Nicolini, Gherardi and Yanow 2004). Therefore, to examine practice, people should be studied in their natural setting; however, the challenge with this work is that we simply do not have access to many of these settings. To accommodate this, we utilise a set of interview transcripts informed by a protocol known as the ‘Critical Incident Technique’. We conduct an analysis inspired by grounded theory to develop a coding scheme that identifies some specific practices that students engage with when they are studying computer science outside of the classroom.

3. How can we characterize the structure of the different places that students use to support their academic study in our home institution?

Understanding computer science students' use of space to support their academic studies provides us with a more complete picture of their learning; however, many of the spaces identified are beyond our academic control or influence. To approach this research question, we will look at several spaces built by our home institution and attempt to characterize them. To do this, we will use Gee's (Barton and Tusting 2005) work on semiotic social spaces as a framework to describe the structure and design of these places with reference to the practice that occurs within them.

Chapter 2 - What spaces do computer students utilize outside of formal activity?

The first task of this research was to identify the spaces that students go to or inhabit in some way to support their academic work. One of the challenges with this task is that the formal data, such as student timetables, is restricted to spaces where attendance is scheduled and compulsory and identifies where we would expect students to *be*, rather than where they actually *are*. Instead, for the purposes of this research, we developed an instrument that would allow the students to show us the places that they actually use for academic study and allow inclusion of any kind of space, and so not biased towards spaces created by the university for the purpose of formal study. This chapter will also examine the role of these spaces and how they become “places” for formal and informal study.

2.1 Related Work

Researchers like Donna Lanclos (Kim Wu and Lanclos 2011) and Lesley Gourlay (Gourlay 2009; Gourlay 2010) have approached the mapping of student use of space through the use of cognitive mapping exercises with groups of students. In their multi-step method, as described by the Ethnographic Research in Illinois Academic Libraries project (Asher, Duke and Green 2010; Asher and Miller 2011), students gradually develop a map of an area by drawing on a whiteboard for six minutes using different coloured pens; the purpose of the pens is to capture what element of the map the students drew first, second and third. The first part of this process is to draw spaces that the student uses for academic study within an area of interest; this can be confined to a room, a large space like the library or more general, covering a campus. The student then annotates the map, using arrows, of their usual movement

between/within these spaces. Finally, the student overlays this map with icons that represent the activities and physical resources they frequently use. Once the mapping process is complete, the map that each student produces is used as a stimulus for one-to-one interviews that explore why the student works in those spaces (rather than others), their patterns of work and their perceived control of that space.

This approach was effective in revealing how groups of students perceive and manage boundaries between private, professional and study activities, in identifying the diversity of spaces used for study and recording their engagement with academic resources; however, a problem with the produced maps was that they can be ambiguous and difficult to interpret – particularly when inter-comparing maps produced by different students.

A variation of the above mapping exercise is a mapping diary (Ramsden and Carey 2014). In this case, the student is given a map of an area and asked to track their movements over the course of a day; afterwards the student is invited to an interview, using the map to elicit responses. This approach relieves the ambiguity that cognitive mapping suffers from and is effective in providing a quick understanding of where students spend their time; however, this approach requires an increased level of commitment from the students to accurately record their movements. In consideration of our research, this method would also limit the ‘field of view’ of the data we would gather; by this we mean that we would be restricting students to think only about the spaces that we have included on our map, excluding spaces we might not have thought of, which are still academically important to the student.

Photographic mapping is another popular technique (Harrop and Turpin 2013; Briden 2007; Wilson 2016). For this method, participants are loaned a camera and asked to take a set of photos over a period of time; additionally, they might be asked to take photographs of their favourite spaces, areas they would like to change or just requested to photograph each new space they visit. The advantage of this approach is that it is good at revealing greater detail about students' lives and would allow the recording of spaces that we have not considered (or included on a map); however, compared with the other methods, photographic mapping is more invasive and potentially requires the provision of valuable equipment.

A limitation of all the above methods is that they provide no consideration for the use of virtual spaces by students; the use of technology is counted only as a resource, rather than as potentially a 'portal' to online spaces. In contrast to the previous researchers, David White (White and Le Cornu 2010; White and Cornu 2011) focuses solely on the mapping of different virtual spaces and provides the allowance for them to be used as a resource for academic study or as an online 'physical' space. To map this usage by students, White employs the use of a twin axis graph. White's graph capitalizes on his Resident and Visitors theory, which is concerned with the ways that people use virtual spaces. In brief, White's theory posits that a user who is interacting online is operating in one of two modes - the visitor or the resident. When an individual operates in 'visitor' mode, they have a defined goal or task, utilizing the most appropriate tool or resource to meet their current need. A 'physical-world' example of this mode is how a person may use a library: they go there with a specific problem, take out a book or resource that they believe is most suitable and then

return the book once they have finished with it. 'Resident' mode is when an individual develops a social presence in a digital space; they go there to interact with or to be with other people; in this case, the resource used becomes a portal to this digital space. A physical-world example of this is a student who goes to a common room to interact and be with like-minded peers and friends.

To create White's map of virtual spaces, the participant annotates a twin axis graph with the different online space they use/go to; the 'visitor' and 'resident' modes of operation forms a linear scale on the X-axis of the graph, while the type of task, comprised of 'institutional' and 'personal' motivations, forms a linear scale on the Y-axis. The name of each digital space that a person uses for academic study is placed in the appropriate quadrant on the graph; for large digital spaces, for example Facebook, where a participant might be a member of more than one online group, White suggests that the participant should break the space up and map to the most appropriate quadrant the different groups of which they are a member. Once participants have produced their maps, it used as an instrument to elicit a narrative about their use of digital spaces.

Whilst this process is one of the few methods that considers the use of virtual spaces during academic study and attempts to visualize the use of these digital spaces for different kinds of academic tasks, a disadvantage of this approach is that it abstracts the spaces in such a way that simultaneous interactions and navigation between them are lost.

2.2 Diary Study

Informed by this related work on mapping student use of academic spaces, we decided to first identify the general requirements of the data that we wished to gather for our research and then identify a suitable method to capture it. Our data requirements were:

- To identify the physical spaces that students go to during academic study;
- To identify the virtual spaces that students use during academic study;
- To be able to gather data at scale, in order to capture the use of space by entire year-groups of students;
- For the data to be gathered ‘at the time’, rather than as an exercise of recall.
- For the academic study to be ‘authentic’; by this we mean the spaces that students identified were directly related to their work on a real module / assessment.
- To gather data over an extended period of time (one academic term), so we might capture spaces that are occasionally used / notice a change of use.

Because of our data needs, we felt that a diary study would be the most suitable method, as this approach would allow us to quickly learn about how and where students spend their time. A diary is also suitable to use for extended periods of time as diary entries are created ‘in the moment’. Unlike the related work, we chose not to use an interview component at this stage, because we would be conducting subsequent studies on the spaces identified; instead, we would structure the diary in such a way that brief details about the student’s activities (who, what, why) would still be captured.

Previous diary studies have primarily provided students with sheets of gridded paper and to gather the use of space, a pre-printed map; however, as we have identified, a pre-printed map would restrict students to recording their use of space within a pre-defined area, which for our study would either be too confining or lack detail. Furthermore, paper-based artefacts would also likely not survive an entire academic term (12 weeks) of use; whilst we could replace these weekly, this would then become a logistical nightmare. To address these concerns, we chose to develop a mobile application that would allow students to create their diary and record their use of spaces from a digital device (mobile phone, tablet, computer) that they own. The creation of a mobile application also yields a number of additional benefits over a paper-based diary:

- We could use hardware features of the device to capture highly accurate geolocation information, wherever the student is located;
- Utilising a student's own mobile device would remove the need for us to supply hardware for the study;
- The student would not have to remember to carry any additional pieces of 'hardware' as part of their routine;
- We, and the student, retain an element of control over the data that is collected. If a paper artefact was lost with identifying information, data about a student's routine would potentially be revealed; however, storing the data remotely on a secure server, rather than on the mobile device, removes this risk.

Whilst a mobile diary study would support most of our requirements, we still needed to address our desire for data that was directly related to students' work on a real module / assessment. To achieve this, we integrated the diary study into an existing academic module known as "People and Computing" (CO334), a compulsory module taught across two separate campuses (Canterbury and Medway) in the first term of the first year of the undergraduate programme at Kent. We chose this module because one of its assignments lasts for the entirety of the academic term, is done in groups of four-five students, and the final assessment requires that each student produces a reflective essay on their and their group's performance for the assignment (what worked, what they would change, etc.). To encourage the use of the diary application, we designed it to complement the tracking of group work, meetings and individual contribution.

Design of the Diary Application

A technological decision was made to develop a web-based implementation of the diary application, rather than a native mobile application. This was motivated by a number of reasons:

- Platform Independence –

Students are likely to have access to a variety of digital devices, for example, mobiles, laptops and tablets, which they will utilise depending on their suitability to a given task and their current location (they would not be using a personal desktop computer in a campus bar!). A web-based implementation would allow the diary application to be accessed on a number of different devices and therefore increase its accessibility in different spaces. From a development prospective,

it would also reduce the requirement to develop implementations of the diary application per device.

- Would not affect the underlying device –

A web-based application would reduce problems associated with deployment of the diary application as it would be unable to make modifications to the operation of a student-owned device. This would reduce a number of ethical concerns as the application would not need to be removed at the end of the study, and when the web application was not on-screen it would be unable to collect any form of data (whereas a native application could be made to collect data continuously in the background). It would also avoid having to deploy the application on device ‘app’ stores, or the alternative of encouraging students to install an unsigned application on their device.

- All functions consolidated to a single interface –

We could collect different forms of data (pictures, files, text) from a single application interface. Related work, such as Lesley Gourlay’s longitudinal study using mobile devices (Gourlay 2010), required students to use native applications on the provided devices; for our study, the use of multiple native applications might risk students not remembering or committing the extra time. From a technological perspective, we would have little to no control over the format, size and naming of files created by third party applications.

- Data stored remotely –

If a mobile device is lost, the data collect would still be preserved securely on a central server. This would allow students to continue participating once the device has been replaced and would also allow us to ensure the destruction of the data at the end of the research to comply with university ethics regulations.

The developed diary application (see Figure 2) was designed to support the keeping of a personal diary by each member of a project group. When a student created an entry using the application (see Figure 3), they were presented with a number of fields:

1. Where are you? (Free text);
2. A description of what you are working on (Free text);
3. Who are you with? (Free text);
4. Work type (Group meeting / Individual contribution);
5. Project notes (Free text);
6. Arrival time and departure time (Scrollable Date/Time Picker)
7. Project files (Remote file upload – photo, document, etc.)

Initially the ‘Project Files’ feature provided support for uploading pictures taken by a device’s camera. This feature was subsequently expanded to support any media type at the request of several project groups. In addition, for each opening of the application the device would request to use the geolocation provided by the mobile device; this could be activated and deactivated by the user at any time.

Once a diary entry was created, it was visible to all members of the project group through a ‘view group diaries’ page; diary entries on this page were read-only. A student could also view their own diary on a separate page and from this, was able to edit any entry.

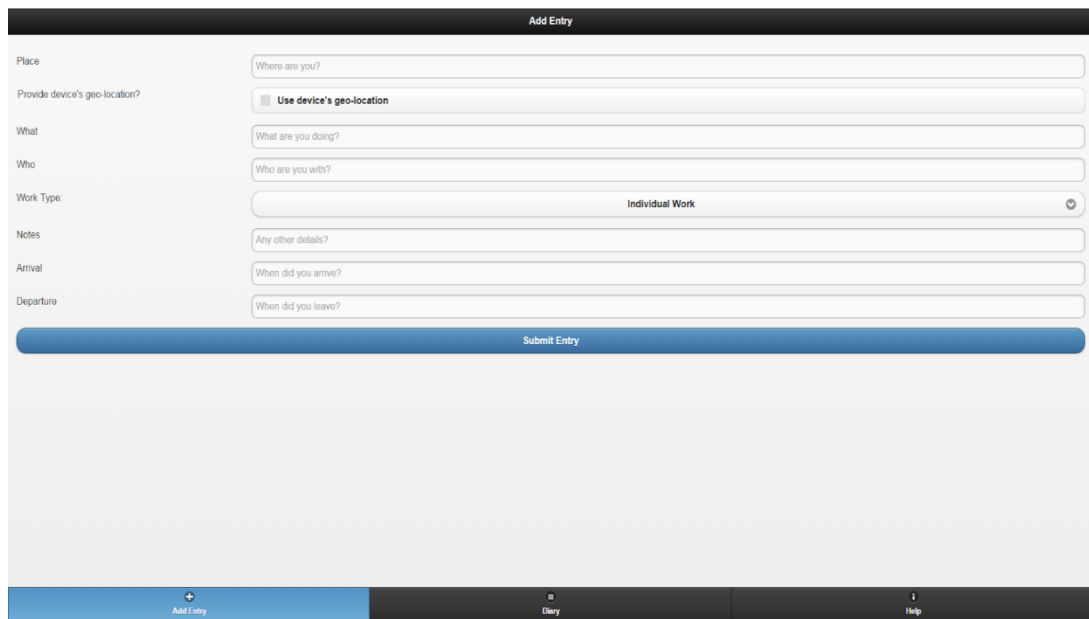


Figure 2: Diary Application - Create Diary Entry Interface

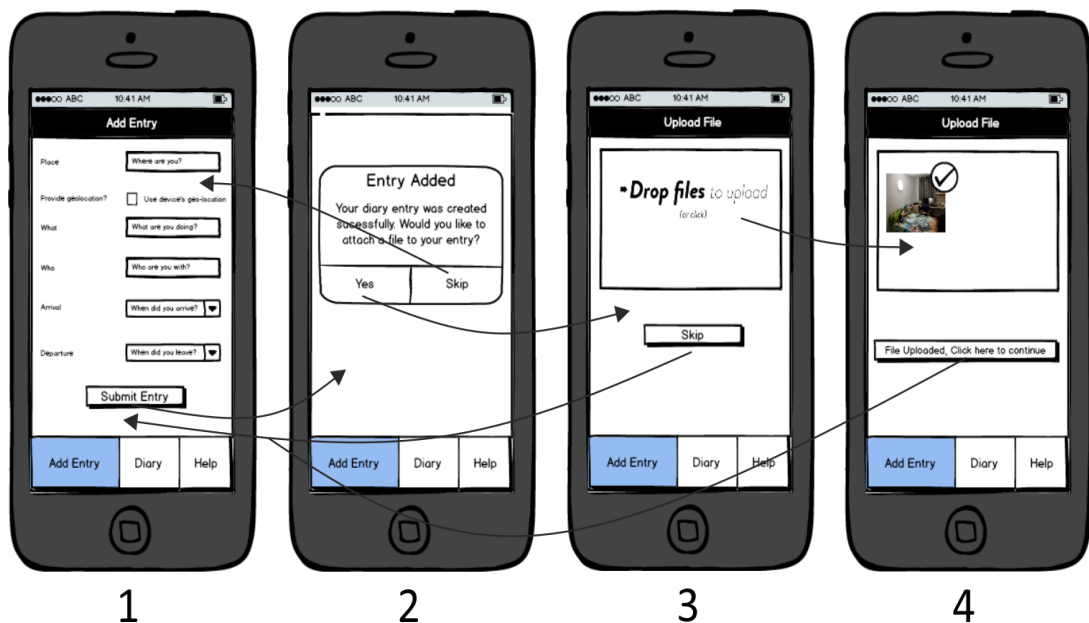


Figure 3: Diary Application Wireframe - Process for Creating a Diary Entry

Use of the Diary Application

The diary application was introduced to the People and Computing student cohort at the beginning of the group project assignment; they were strongly encouraged to use the application, but its use was not compulsory and credit was not awarded to those who did. Students were provided with these instructions:

“Use the tool, from your phone or desktop, noting every time you do something related to your project. If you can, take a photograph of each place you work in and any artefacts you are working on (e.g. inspirations, sketches and prototypes)”.

Across both campuses, there were 235 students enrolled on the first-year undergraduate programme (172 students at Canterbury and 63 students at Medway). For the assessment, there was a total of 55 groups, each comprised of 4-5 students (40 groups at Canterbury and 15 groups at Medway). 128 students used the diary application at least once during the 12 weeks (101 students at Canterbury and 27 students at Medway). The average number of diary entries created by each student was five. Figure 4 and Figure 5 illustrate the weekly number of diary entries created by students from each campus during the autumn term; as the two figures show there appears to be no significant differences between the two campuses and the use of the diary application. The noticeable drop in the number of diary entries created for the week starting 04/11/2013 is because normal teaching is suspended at both campuses; instead, students are encouraged to spend this ‘reading week’ working on projects. In addition, as each class is supervised by a PhD student, we were concerned that a class supervisor might enforce the creation of diary entries in the application (as there’s a reflective writing component at the end of the module). We compared the distribution of entries created across all class groups for People and Computing and

found no anomalies; as such, we believe the class supervisors did not influence the number of diary entries recorded.

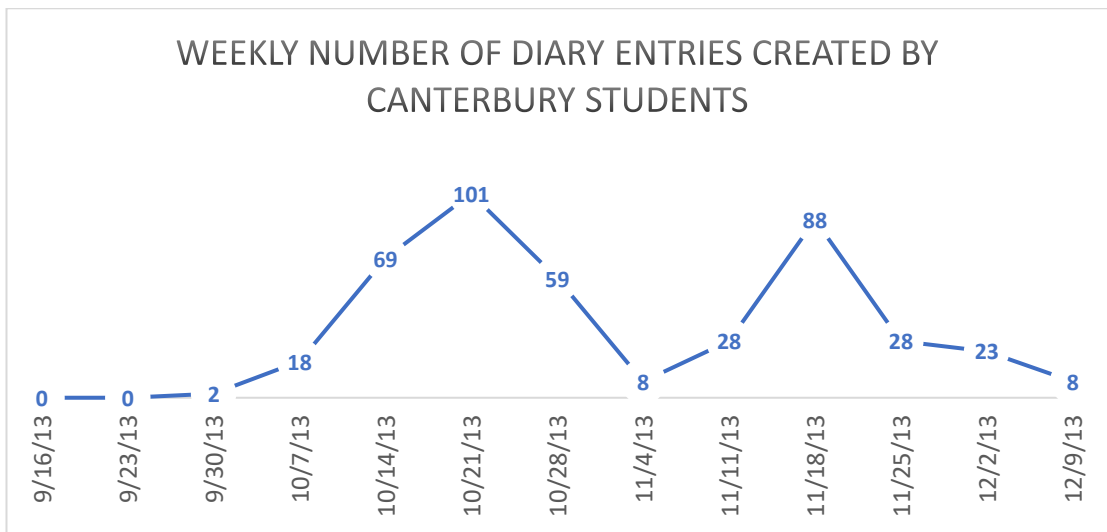


Figure 4: Weekly number of diary entries created by students from the Canterbury campus

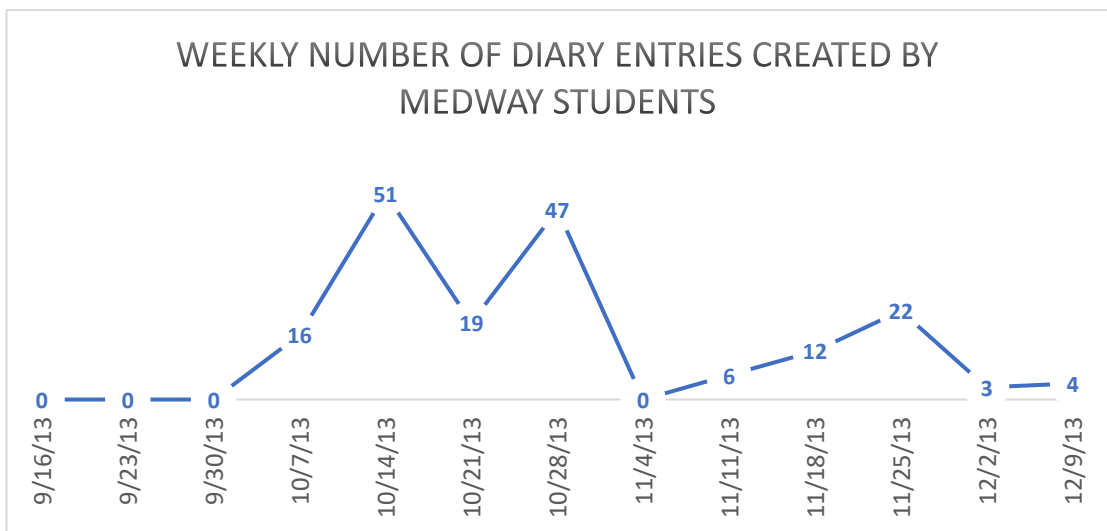


Figure 5: Weekly number of diary entries created by students from the Medway campus

The entire dataset comprised of 675 diary entries and 202 of these entries included a geolocation (GPS); these were created by 73 unique users. A common feature of the dataset was that students rarely provided an accurate description or geolocation for their term time home address; instead, they simply referred to it as 'home'. For all other locations, the description was quite detailed, for example 'Rutherford Quiet Room' or 'Darwin Seminar Room 14'; this suggests that students self-regulated the amount of detail that they were willing to provide to the diary application. By using the descriptive location field, we were able to append a geolocation to an additional 327 diary entries. 54 of these appended geolocations were for entries where the location field was labelled as 'library'; in these cases, we used the student's local campus (either Medway or Canterbury) to decide which library (Templeman or Drill Hall) to identify.

Visualising the Data

Using the descriptive location field of the dataset, we plotted the frequency that each location was visited. The graph, Figure 6, represents the use of space for the entire twelve weeks and does not discount multiple visits within that timeframe to the same space by the same student. Because the locations described by students were created for different purposes, to aid the reader we have also grouped them by type (Table 1).

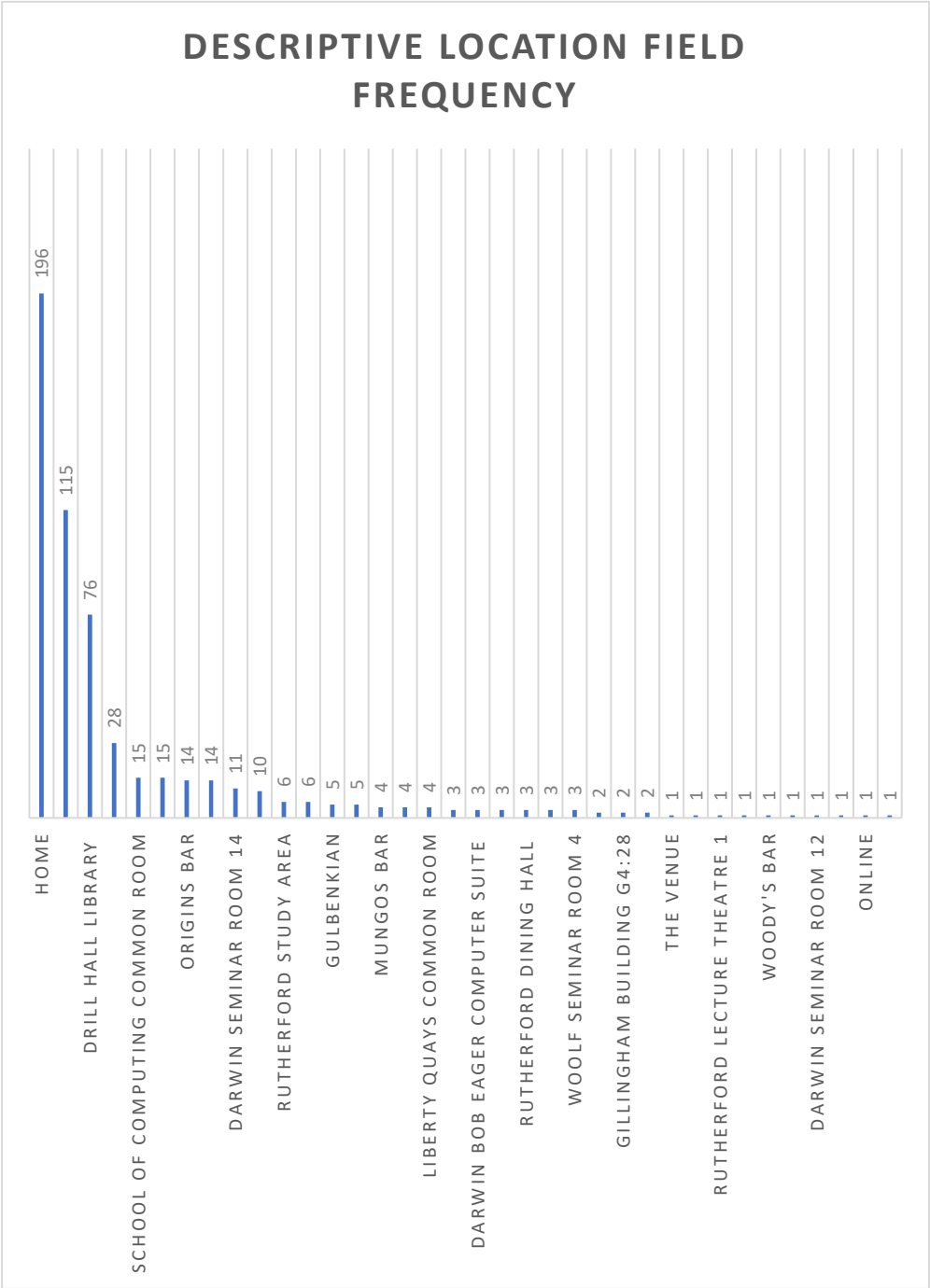


Figure 6: Diary Entries – Frequency of Locations

Type	Descriptive Location	Campus
<i>Café / Restaurant</i>		
	Origins Bar	Canterbury
	Gulbenkian	Canterbury
	Mungos Bar	Canterbury
	Dolche Vita Café	Canterbury
	Rutherford Dining Hall	Canterbury
	Marlowe Create Café	Canterbury
	Woody's Bar	Canterbury
<i>Other Facility</i>		
	Cinema	Canterbury
	The Venue	Canterbury
	Sports Centre	Canterbury
<i>Social Space</i>		
	School of Computing Common Room	Canterbury
	Liberty Quays Common Room	Medway
	School of Computing Common Room Medway	Medway
<i>Study Space</i>		
	Templeman Library	Canterbury
	Rutherford Study Area	Canterbury
	Darwin Bob Eager Computer Suite	Canterbury
	S.115b Meeting Room	Canterbury
	Drill Hall Library	Medway
<i>Timetabled Teaching Space</i>		

Type	Descriptive Location	Campus
	Rutherford Seminar Room 5	Canterbury
	Marlow Lecture Theatre 1	Canterbury
	Darwin Seminar Room 14	Canterbury
	Gulbenkian Seminar Room	Canterbury
	Coyler-Fergusson Seminar room	Canterbury
	Woolf Seminar Room 4	Canterbury
	Rutherford Lecture Theatre 1	Canterbury
	Darwin Seminar Room 12	Canterbury
	Grimond Seminar Room 4	Canterbury
	Gillingham Building G4:12	Medway
	Medway Building M3-04	Medway
	Gillingham Building G4:28	Medway
	Medway Building M2-10	Medway
	Gillingham Building G4:05	Medway
<i>Online</i>		
	Facebook	Virtual Space
	Online	Virtual Space

Table 1: Diary Entries - Descriptive Locations Grouped by Type

Whilst a frequency graph of the descriptive location field provides an indication of how often students visited different kinds of spaces for academic study, we also desired a visualization that would allow the geographical location of these spaces and their proximity to one another to be interrogated.

Literature on the occupancy of study spaces (Roberts and Weaver 2007; Ramsden and Carey 2014; Gullikson and Meyer 2016), regularly employ the use of heat maps to identify patterns of academic space use within an area. In a similar fashion, we utilized the geolocation data gathered from the diary application (529 entries) and developed an interactive application, using Openlayers 3 (*OpenLayers* n.d.) and an Openstreet Map Tileset (*Standard Tile Layer - OpenStreetMap Wiki* n.d.), which would overlay the geolocation data on a topographical map. Figure 7 provides a reference guide for understanding the heat map images that will follow. For each region on screen, the application would cluster nearby geolocation entries based on the current map zoom level; for example, zooming out to the UK would mean clusters will be formed by an aggregation of geolocation points within towns, whereas zooming into a specific campus would mean the clusters represent geolocation points within buildings - the number of entries within a cluster is indicated on the map. It is also important to note that the same clustering is used on all of the heat map images of the same area and zoom level - we use a boundary box to indicate areas of interest on each image. Because we don't have the geolocation for many locations that were labelled as 'home', we were unable to plot these (128 entries).

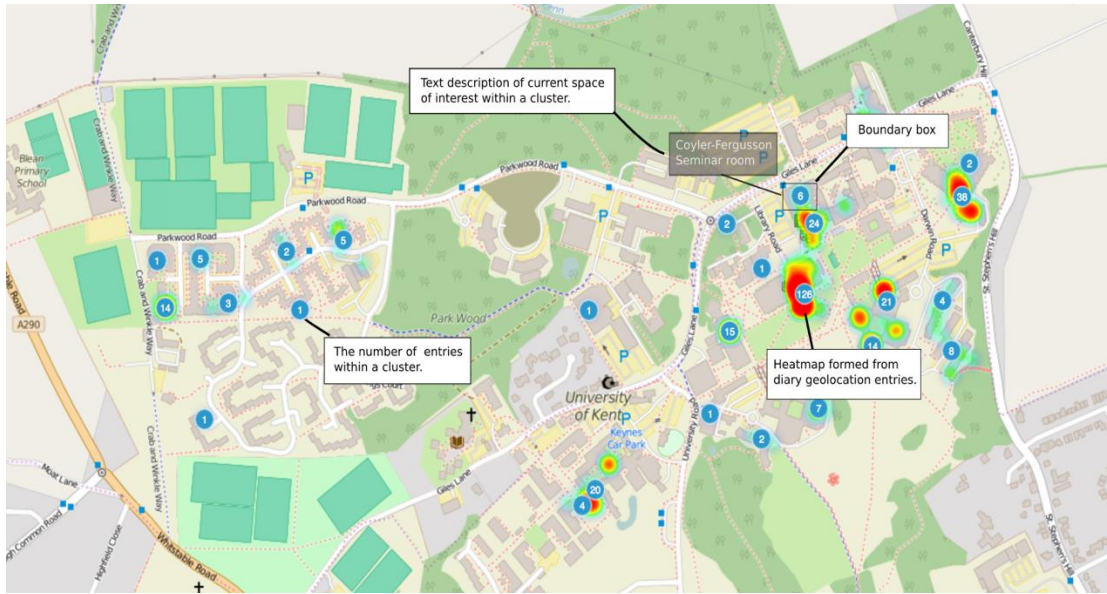


Figure 7: Guide to Heat Map Images

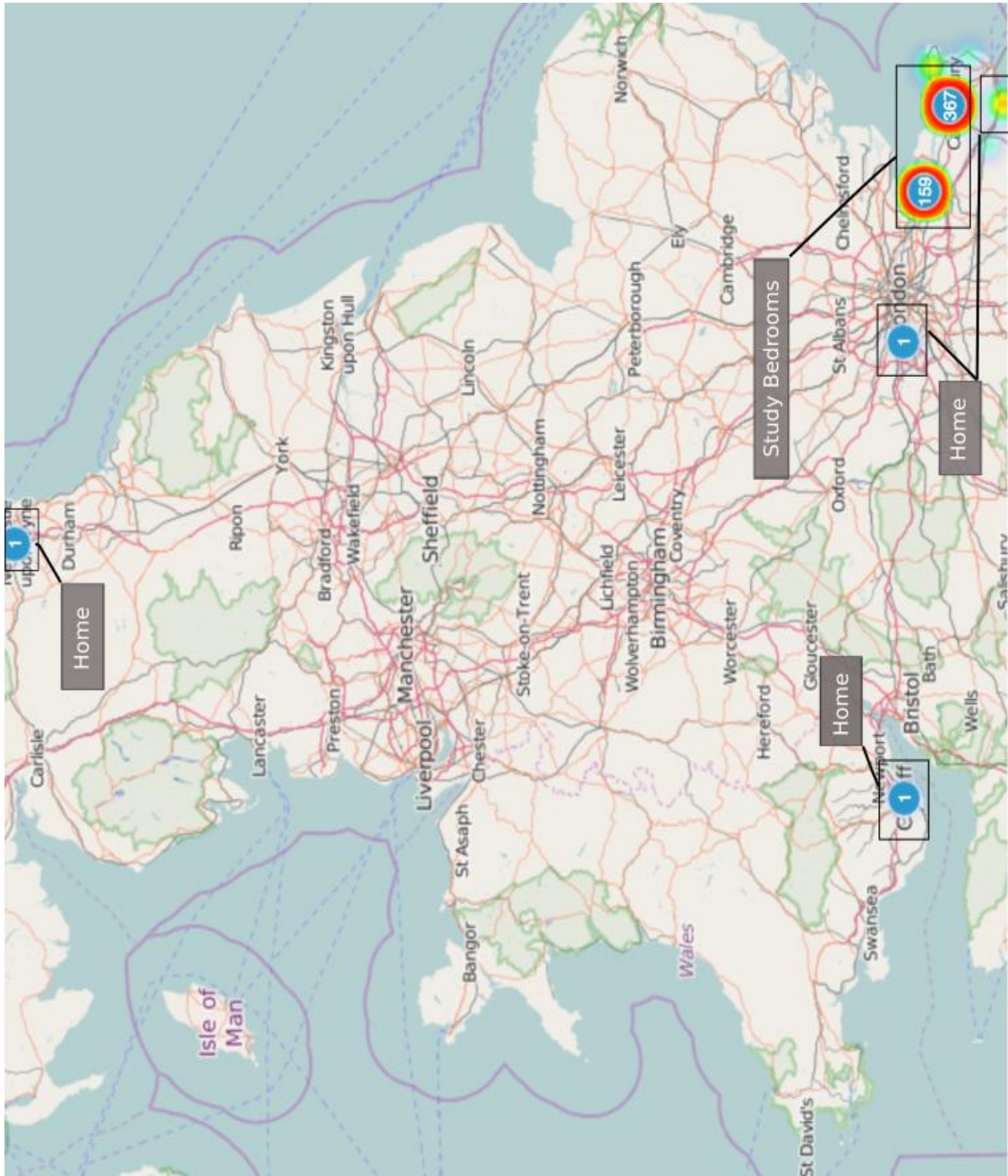


Figure 8: Personal Spaces - U.K

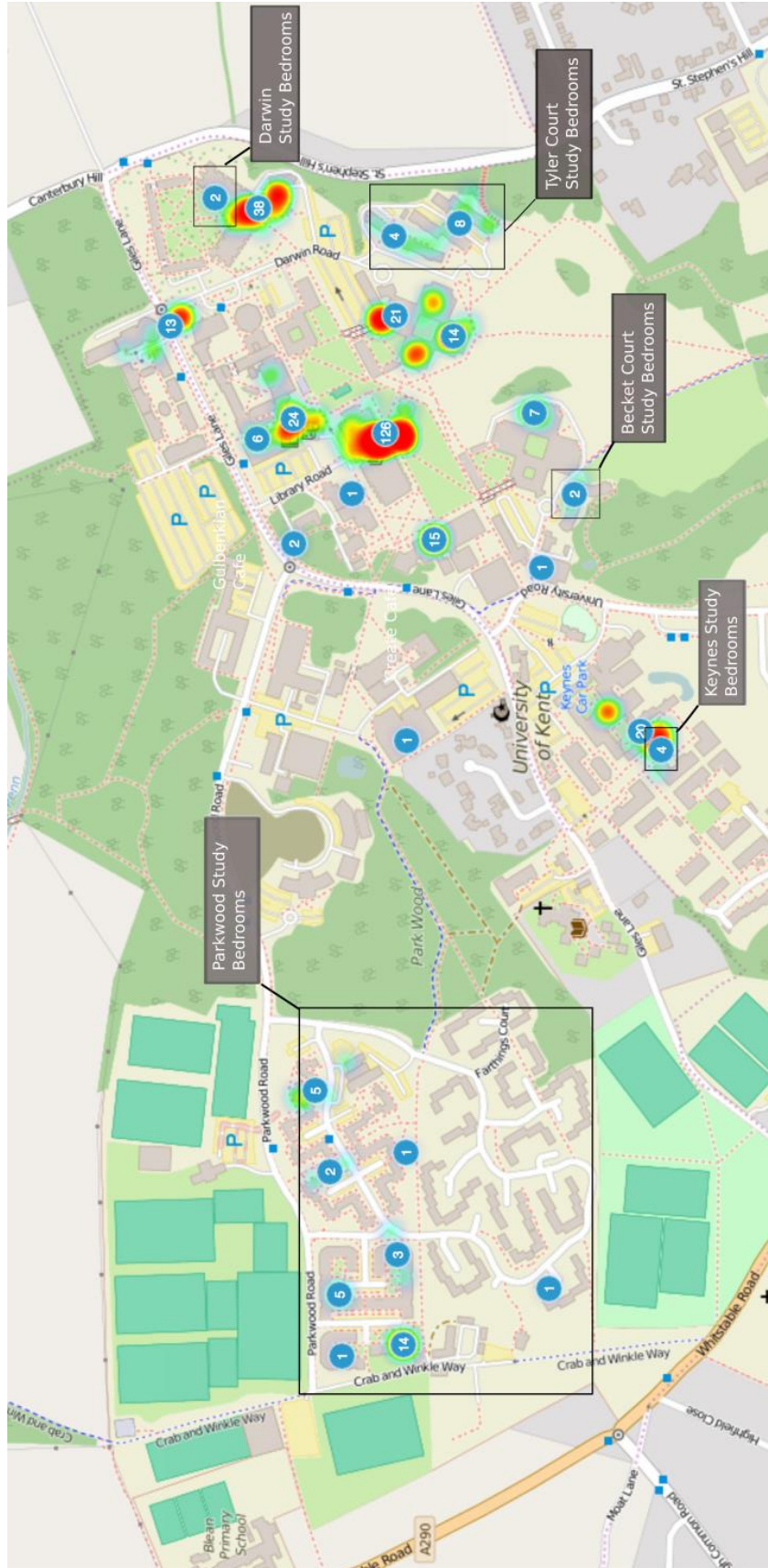


Figure 9: Personal Spaces - Canterbury Campus



Figure 10: Personal Spaces - Medway Campus

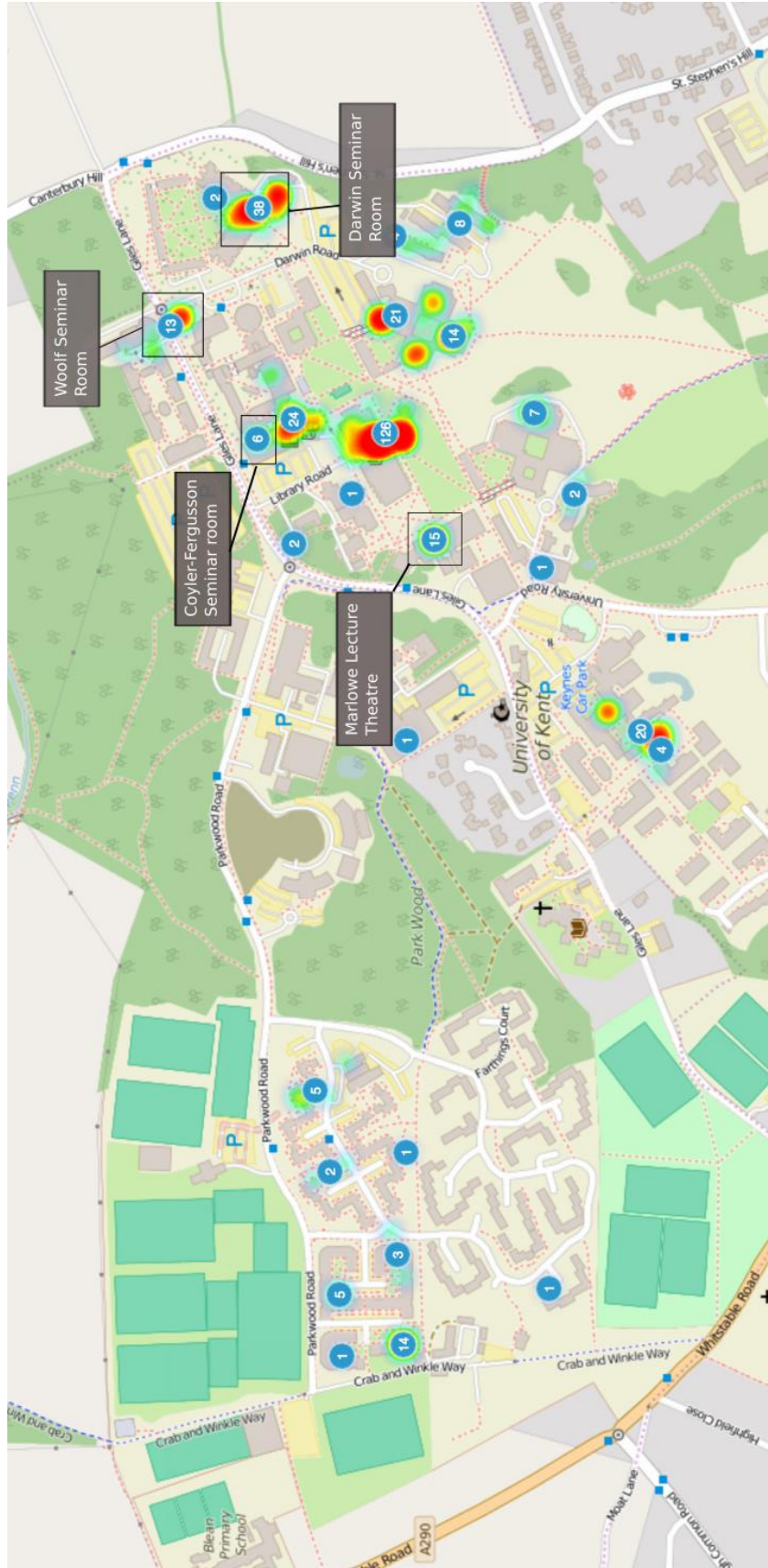


Figure 11: Exploiting Timetabled Space - Canterbury Campus



Figure 12: Exploiting Timetabled Space – Medway Campus



Figure 14: Formal Study Spaces - Medway Campus

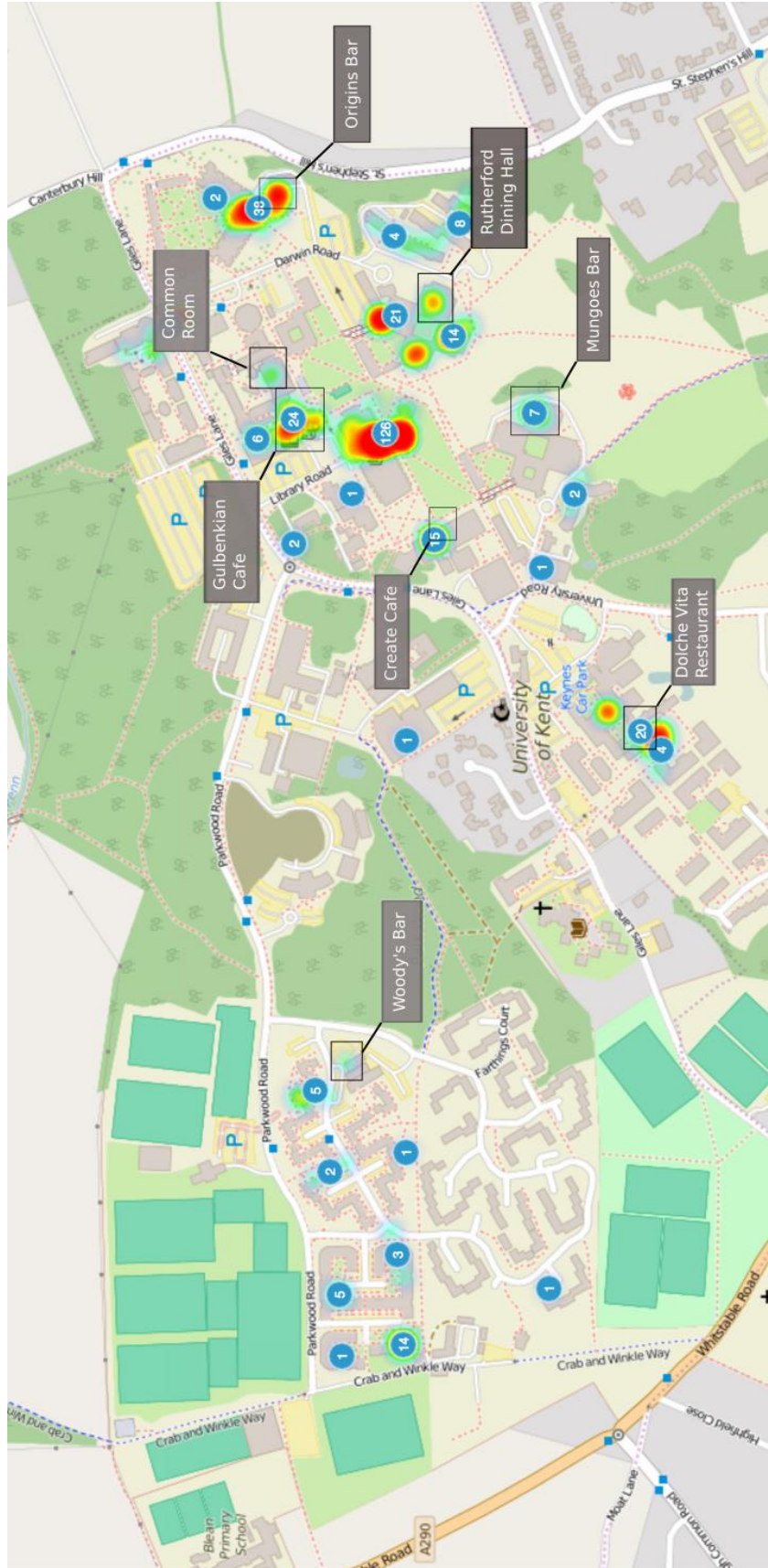


Figure 15: Third Places - Canterbury Campus



Figure 16: Third Places - Medway Campus

What the data revealed

In most cases, we were unable to differentiate geographically where a student's 'study bedroom' was, however, it was the most common place (196 entries) described in the descriptive location field. Within the locations labelled 'home', 16 students described that they were working in another group member's study bedroom or kitchen, rather than their own home.

Canterbury's student accommodation is distributed across the campus site and is comprised of different types of structure: Parkwood student village contains housing and flats; Keynes and Darwin's accommodation is integrated within a college building and Becket and Tyler Court are dedicated accommodation buildings within the central campus. Furthermore, all first-year students (who selected Kent as their first choice) are guaranteed accommodation on campus; in subsequent years, students mostly move offsite to privately-owned accommodation. In contrast the Medway campus a single, university-owned, accommodation facility (Liberty Quays); this building of student flats is located a short distance from the main campus. In both campuses, free bus services provide a shuttle between the Parkwood Student Village to the main campus and Medway Campus to Liberty Quays.

Unlike the other locations that students use (for academic study), study bedrooms/home are the *only* places where the students have significant control over the design of the space, its access and use. To reflect this, for Figure 8, Figure 9 and Figure 10 we label them as "Personal Spaces".

We can also see from the heat maps (see Figure 12), that seminar rooms within the Gillingham and Medway buildings at the Medway Campus are frequently used by its students, 37 and 19 entries within Seminar Room G4:12 and Seminar Room M3:4; similar use is seen at the Canterbury Campus (See Figure 11) (Rutherford: 21, Marlowe: 14, Darwin: 12, Colyer Fergusson: 6, Woolf: 13 and Grimond: 2). At first glance it seems that this use of the diary application was within timetabled classes and the formal teaching spaces were being used for their primary purpose; however, when we accounted for the timestamps on the diary entries we discovered that this was rarely the case; instead, students were using these teaching rooms *outside* of timetabled teaching hours. Whereas we might have labelled these spaces as “Formal Teaching Spaces”, because that’s what these rooms are designed for, their use outside of timetable hours by students is more exploitive. The heat maps also show us that this kind of use is restricted to these rooms, not other seminar rooms where they have not had timetabled classes; these other seminar rooms, whilst visible, appear ‘off limits’ to the students’. In the case of Medway, the campus is co-operated by three different universities (University of Kent, Greenwich and Christ Church) and each owns its own buildings, with shared ownership of the library. The use of the seminar rooms at Medway shows permissive access; that is, as a student of the University of Kent, students feel that they allowed to use all UoK seminar rooms. In contrast, at the Canterbury campus, the students have access rights to all of the buildings, yet the students exploit a subset of the available formal teaching space. This suggests that at Canterbury and Medway it’s because the students have classes in those rooms that they know of them and their patterns of use; in turn, they then use this knowledge to take advantage of them as a space to work during periods of

empty occupancy. We have labelled Figure 11 and Figure 12 as ‘Exploiting Timetabled Space’.

The heat map images and the frequency graph both show that the library at each campus is the most common study space used by the first-year students (115 entries at Canterbury and 76 at Medway). Both libraries are complicated buildings because they contain a variety of different internal spaces, for example: quiet study areas, group meeting rooms, computer rooms and, of course, aisles of books; however, in only three instances did a student describe the specific space they used; for example, the group meeting rooms, within the library. Other study spaces, Rutherford Study Area and Darwin Bob Eager Computer Suite, were also used by students at the Canterbury Campus (6 diary entries and 3 diary entries respectively). Canterbury Campus has a large number of dedicated study spaces distributed across the site and these contain computer terminals and open space for students to work; in contrast, Medway Campus has little dedicated study space which is not located in the library building. The School of Computing also possesses its own study space on the Canterbury Campus - the Peter Brown Room (a computer room available solely for use by Computing students. This was recorded by students in only three diary entries. Given the availability of study spaces across the Canterbury Campus and the distribution of accommodation and teaching rooms across the site, it may seem surprising that the library is a major ‘hotspot’ for first year undergraduate students. Because these rooms are used by students for their intended purpose (as study spaces), we have labelled Figure 13 and Figure 14 as ‘Formal Study Spaces’.

A geographically distributed set of spaces used were cafés, bars and common rooms on both campuses. As we have already described, the range of facilities at the Medway Campus is significantly less developed than those available on the Canterbury Campus. Medway does have some cafés, but these were unused for academic work by the students; instead, two common rooms, one located in the Medway Building (where the School of Computing at Medway is located) and the other at Liberty Quays (student accommodation) were used for academic work. The use of these two locations, rather than the other available cafés, suggests that these spaces were used because of their locality to other activities. At the Canterbury Campus, all of the available café / dining facilities were additionally used as a space for academic work. Because of the design of the campus, these facilities are distributed across the campus near to accommodation, timetabled teaching rooms and within college buildings. Some of these facilities are remote from the formal study space / exploited timetabled space that we identified in the other heat maps, yet these spaces were still used heavily by the students, again, suggesting that these spaces were used for their proximity to the students. This use of cafés, bars and common rooms as a place for group based academic study, matches Oldenburg's definition of 'Third Places' (Oldenburg 1998); places whose characteristics afford comfortable, safe spaces, where people can come and share conversation. Whilst these spaces are not primarily designed for academic study (unlike study rooms); their use remains prevalent by the cohort (51 mentions in the descriptive text locations). Because of this, we have labelled Figure 15 and Figure 16 as 'Third Places'.

In terms of virtual spaces, on three separate occasions, students specifically mentioned Facebook as a space that they utilized during their project – for these instances they were all marked as “a group meeting”, two were a discussion about an assessment deliverable and another was a meeting to decide on a project focus.

Whilst this information does indicate to us that students use virtual spaces to support their academic work, at this stage we lack detail about how this space was used and why the group chose to use it instead of one of the available study spaces on campus.

2.3 My Programming Week

Whilst the diary application provided us with the ability to see the spaces that a cohort of students uses to support their academic study, it lacked detail about their activities in those spaces. Literature previously discussed commonly uses artefacts produced by students as a stimulus at interview; as such, we repeated this first study with a smaller group of students, but with the addition of an interview component. We based this on ‘My Programming Week’ (Fincher, Tenenberg and Robins 2011), which used a diary exercise and a narrative interview. In contrast with our twelve-week diary study, participation for My Programming Week took place in a single week, selected by researchers based on known upcoming programming assignment deadlines.

The interface of our diary application required minimal adaptation for My Programming Week; this consisted of removing the “group” diary features from the application and we provisioned the interface with these fields:

1. Where are you? (Free text);
2. A description of what you are working on (Free text);
3. Who are you with? (Free text);
4. Arrival time and departure time (Scrollable Date/Time Picker)
5. Provide a geolocation (Geolocation API, if available)
6. Upload a photo (HTML5 ‘camera’ upload functionality)

For the interview component, we used the protocol described in the original My Programming Week study

“First provide the participant with a copy of their diary (ideally this should be a printout). Explain to them that it shows all events that they recorded using the diary web-application during their week of programming. Explain that it is in chronological order, but they do not need to give a chronological account of their week if they do not feel it is appropriate. Pictures that the participant took using the web-application should be provided on separate printout. Provide time for the participant to look through all of the materials and tell them that they can use any of them during the interview.

Ask the participant to provide an overview of their week; was it typical / atypical, what were their personal priorities (were they going home, was someone coming to visit, etc.) and what academic work had they been working on.

Ask the participant to narrate the events of their week. In cases where a student discusses an event that they had not recorded in their diary, details should be encouraged (frame these in a similar format to those asked by the web-application). Students should be queried as to why they had not created an entry in their diary; was it by accident or intentional?

For the final part of the interview, focus should be made on the spaces that the participant went to during their week of

programming. Probe for the reasons for working in that space - why did they go there, what happened and with whom did they interact?” (Fincher, Tenenbergs and Robins 2011)

Participation

Participation in our previous diary study consisted of first year undergraduate students at Medway and Canterbury using our diary application within an academic module called People and Computing. For our My Programming Week study, we were interested in students working on *any* programming related activity; because of this, participation for this study recruited students from programming classes of the first- and second-years of study at the Canterbury Campus - four first year and three second-year undergraduate students volunteered.

A total of 54 diary entries were created by the two groups of students and 19 of these entries included a geolocation. A feature of the previous dataset was that the students rarely provided an accurate description or geolocation for their home address, and we encountered a similar problem with this dataset. As before, we used the descriptive location field to append a geolocation to 11 additional entries. The remaining entries without a geolocation were labeled as ‘home’ (19 entries) and ‘the train’ (5 entries by the same student).

Visualising the Data

Using the descriptive location field of the dataset, we plotted the frequency that each location was visited; the graph Figure 17 represents the use of space during the week of study and does not discount multiple visits within that timeframe to the same space by the same student.

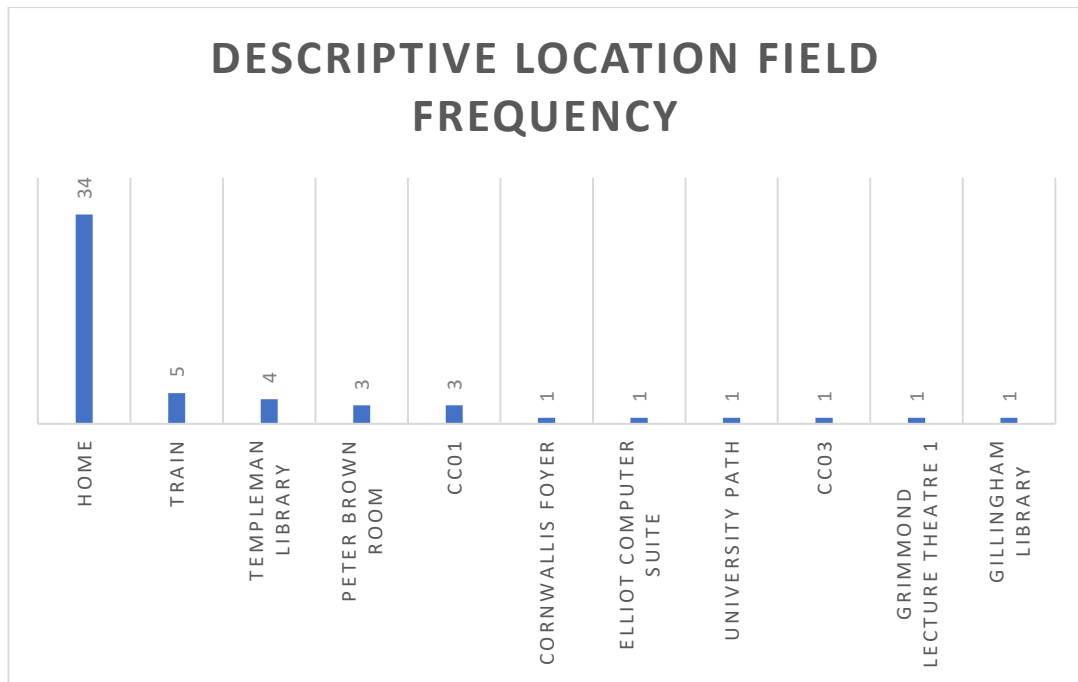


Figure 17: Location Field Frequency

As before, we also generated heat map images of the data to visualise geographical proximity. As the participants were comprised of first and second year undergraduate students, we generated two separate heat map images so that we could see any difference between the use of space by the two cohorts. The students used a smaller number of spaces than our first diary study and we annotated all areas of interest in each image.

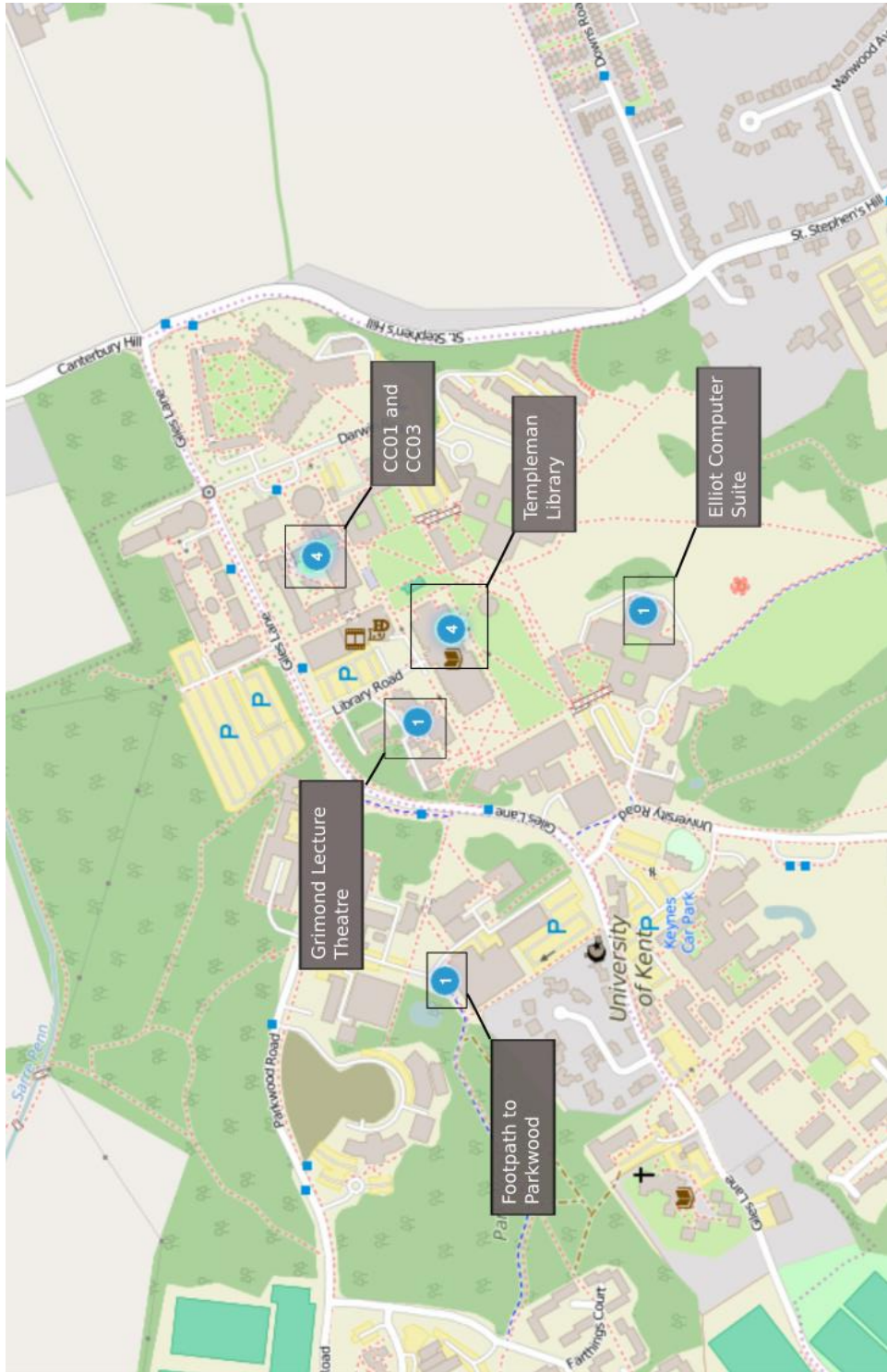


Figure 18: Use of Space - First Year Undergraduate Students

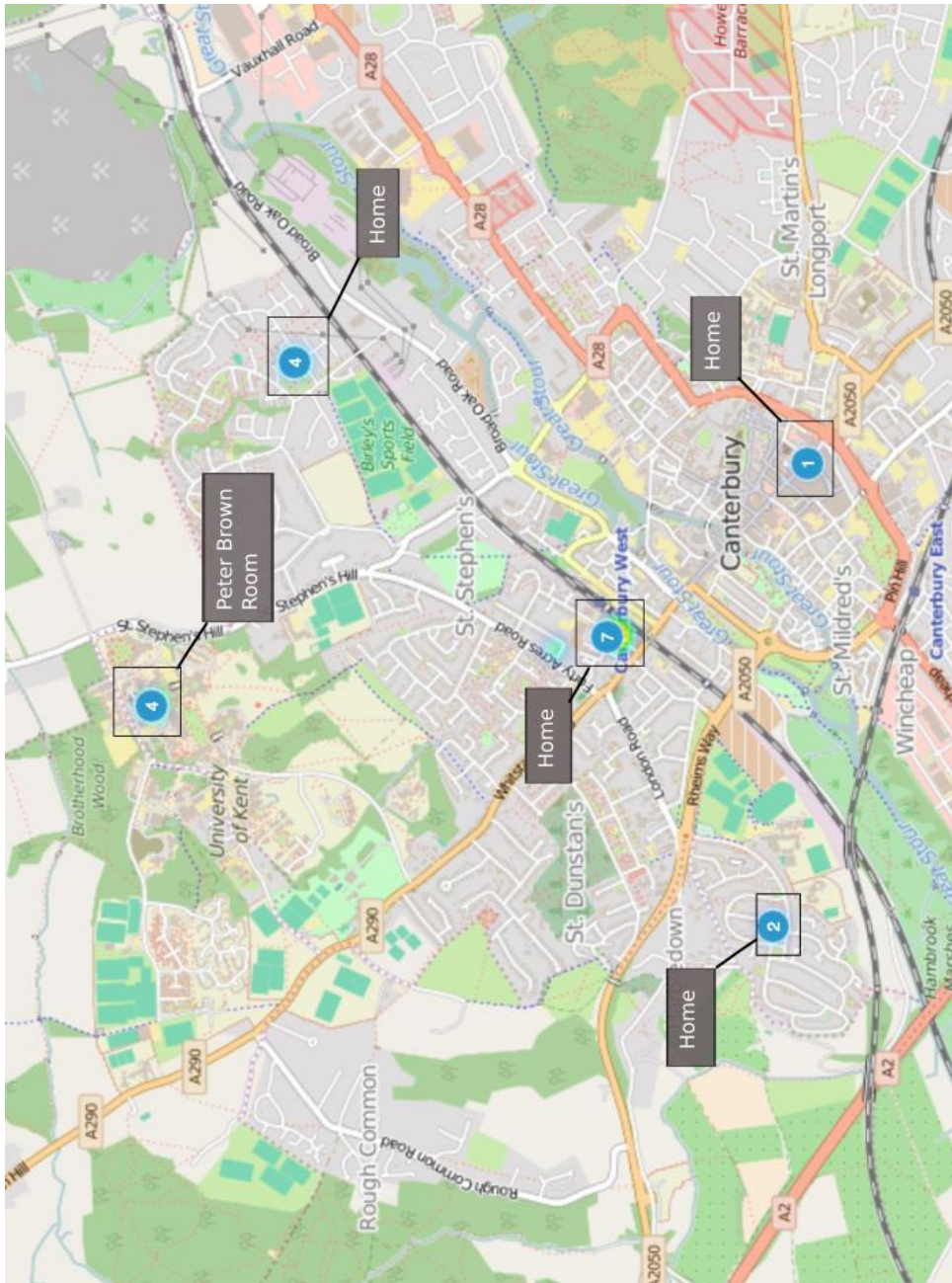


Figure 19: Use of Space - Second Year Undergraduate Students

Discussing the Data

In our first diary study, the space that students used the most to support their academic study was their “home” / “study bedroom”; as shown in figure 17, student’s “home” / “study bedroom” was the most used space. When we visualise this data on our heat map images (Figures 18-19), we can see that none of the first-year students provided a geolocation for their study bedroom; however, all of the second-year undergraduate students did. If we compare the second year’s heat map image with earlier heat map images of personal spaces (Figures 9-10), we can clearly see a difference between the first and second years; as expected, the second years’ personal space is distributed off-campus around the City of Canterbury, whereas the first-year students are (mostly) situated on the Canterbury Campus site. This is not surprising as we already know that the first-year students are guaranteed accommodation on campus, but what is significant is the distribution and distance from campus of the second-year students compared with the distance of the first-year students to university buildings –second-year students will need to travel a greater distance from their home to the university. To put this into perspective, from the centre of Canterbury to the Cornwallis Buildings (the School of Computing) would take: 37 minutes by foot, 15 minutes by bicycle or 23 minutes using the University Bus; compared with: 16 minutes by foot, 5 minutes by bicycle or 12 minutes using the University Bus for the university accommodation (Parkwood) located furthest away from the School of Computing. Because of this distance, we might expect that the second-year students will spend more time working in their own study bedroom or using the available study rooms on campus.

However, when we refer to the heat map images (see Figures 18-19), we see that this is not necessarily the case. In our first diary study, the first-year students used a variety of different types of spaces on campus: the library and other study spaces, exploiting unoccupied teaching rooms and using third places (bars, cafés and restaurants); however, this variety disappears for the second-year students – instead, during the My Programming Week study, they exclusively used their study bedrooms or the Peter Brown Room. Initially this lack of variety is surprising, as we might expect that as the students become *more* aware of the different spaces that are available to them, their use of these different kinds of spaces would increase. One possible reason for this difference is that the participants of the first diary study were working on a group assignment, whereas the My Programming Week participants were working on individual programming assignments. So, the first-year students might have used spaces that they deemed suitable for group work, whereas the My Programming Week participants did not have this need. Another observation, is that the first diary study was twelve weeks in length compared with the single week of study for My Programming Week and that a greater variety in the first diary study was to be expected. However, despite these observations, it still remains the case that the first-year My Programming Week participants used the Templeman Library and the Computer Suite, spaces that we encountered in our first diary study, but the second-year students did not.

My Programming Interview Transcripts

In this section we will focus, in turn, on the interviews that were conducted with the first- and second-year students. Each interview lasted approximately one hour and was audio recorded; the audio files were professionally transcribed. The transcripts

were annotated by the principal researcher of this thesis, with reference to the original audio tape and diary artefacts. All names in the excerpts of transcripts that follow have been replaced with pseudonyms.

One of the observations made in our first diary study was how the first-year students would utilise 'Third Places' across campus. None of the participants of the My Programming Week study included these spaces in their diary entries, whereas all of the first-year participants of this diary study did, during their one-to-one interview.

Percy: "... I had to get one of our group presentations together because me and my group had to meet up to make sure the presentation was done. So, we thought that's a place we can meet [the common room]. But no, sometimes we meet – we've met in Woody's [a bar in Parkwood] before during the day when it's a bit quieter."

In this, Percy reinforces the proposition that students went to these kinds of spaces because they were more suitable for group work.

Interviewer: "Who was that with?"

Percy: "That was with my first People and Computer group. We had to make a video. We met in Woody's because most of us live in Parkwood, so we thought "Okay." Then we filmed around the area, then we went back to Duck's house – I forget his second name. No, wait it wasn't Duck... Someone's house in Parkwood."

Here, Percy suggests that proximity to their homes was an important factor when deciding which place to go to

Interviewer: "Why did you choose Woody's and not go straight to someone's place then?"

Percy: "We chose Woody's because A) we all know where it is, and I don't know, it just seems a lot cleaner than just walking up to someone's house, knocking on the door, saying "Can I come in?"

and everyone sitting round. Because we didn't know each other as friends, we just felt a bit more right to be up at a neutral location, I guess."

For Percy's group, 'Woody's' is a place all the group members know. Percy also makes a clear distinction about his group: comprised of peers, rather than friends; because of this, Percy believes that it would not be 'right' to go straight to their homes. Instead, Percy states that Woody's served as a 'neutral location', reinforcing our original labelling of these kinds of places as 'third places' (Oldenburg 1998). In a separate interview, Thomas provides a non-group work related reason for going to these spaces:

Thomas: "Origins [a bar in Darwin, Central Campus] is probably the other one, because we sometimes get a two or three-hour gap between lectures. We normally go there, because two hours is not quite worth going back. So, we end up going to Origins and having lunch there.

Interviewer: "So it's not worth going back to Parkwood?"

Thomas: "Yes, so we just go to Origins to have lunch. Like we do that in one of the one hour gaps and on Fridays where I think we've got a two-hour gap. So, we buy lunch there."

Interviewer: "So you go to Origins to just socialize then?"

Thomas: "Yes, normally its Rose, Toby, Glyn and myself. Then sometimes Donald and Douglas, depending. Because they live in Darwin it's just like "Okay, I might as well go home." So sometimes they come, sometimes they don't."

For this group, proximity to other places is still an important factor for why they go to different places, but unlike Percy's group, it is the bar's proximity to teaching spaces and the teaching space's distance from their homes that make it a space to go to.

In an interview with another first-year student, Henry, space use during gaps between teaching hours also emerged. In this case, his use of space was dependent on the weather:

Henry: *“When it is warmer we were sitting outside, but we come up to the computer science common room because it’s cold and rainy.*

The computer science common room is okay, but it’s difficult to find a seat at lunchtime. It’s not very big, and it doesn’t have desks. Well, it has a desk, but it’s not what I’d want. It’s difficult.

We also have a problem with plugs. Plugging in laptops is tricky, because there are plugs along the walls, and some in the floor, under covers, but you have to run wires around people if you’re not sat in the right place, and that sort of thing. It’s not great... I think it’s designed with the intention of, ‘sit down and have a cup of coffee’, rather than, ‘sit down with your laptop’; which makes sense, but because I’m nerdy enough, I quite like having my laptop out and about.

So, I’d rather there were large, square, specifically desks, because round desks I find you can’t do an awful lot with, because the bits at the side, you have to have things hanging off to be at the right angle. I’d rather they curved the other way, obviously, that’s impossible”.

Henry’s discussion about the common room provides an interesting insight into what he believes this room was designed for - ‘sit down and have a cup of coffee’, and how he wishes to use this space to - ‘sit down with your laptop’. Henry identifies that one of the major problems with this space, for him, it’s the positioning of the power sockets and the shape of the desks; his focus on these shortcomings, is strange given that the place he goes to during the warmer, drier months (outdoors) doesn’t have any of these items. Furthermore, next door to this common room is a room with both straight desks and plug sockets along them (the Peter Brown Room); Henry however, chooses not to go there, despite having the physical attributes that he desires.

The most commonly used space in both the first and second diary studies was the use of study bedrooms / home. Throughout the first-year interviews, the students spoke about these spaces.

Percy: "If I'm doing anything to do with the university, if I'm not in a lecture or a seminar, I tend to do it at home. I've done all the coding assignment at home. I've done all the math's assignments at home. The only one which I actually had to leave for was the People and Computing one, and that's because it was a group project, so I sort of had to, though I would rather have not.

.. I nearly always have my door shut in my room. I try to keep it fairly quiet as well. I will nearly always listen to music through headphones, if I'm listening to music, that sort of thing, just because it keeps me a bit more relaxed.

If I want to go and talk to people, I'll go outside my room, which I do. But, if I'm in my room, I'd rather have my privacy and choose precisely who I'm talking too."

Percy's remarks about his personal space confirm that these spaces are important to students because they are the only spaces to which they are able to control access.

For Percy, privacy is an important aspect of his space and he indicates this to his house-mates by closing the entrance to it to others. Thomas also reported a similar characteristic of his study bedroom:

Thomas: "Normally my roommates don't come in. The door's left open, but to, if you get what I mean. The other day Toby just walked in and I was like 'what the hell are you doing? Who let you in?' that was a bit odd. But yes, they're welcome to come in, but they don't. Everyone in our house just kind of keeps to themselves and what not."

Unlike Percy, Thomas keeps his door ajar, indicating to others that he is in and they could enter if they wish, but normally they choose not to; however, control over

access to their flat (and his room) is still important to Thomas because of his reaction to his friend Toby walking in – ‘what the hell are you doing? Who let you in?’.

However, whilst working individually in their study bedrooms might be common, it wasn’t restricted to this. Thomas also spoke about going to Toby’s study bedroom to work:

Thomas: “He’s literally in the court across the road from mine, so I literally just say ‘I’m coming around’. I walk round, his room is nearest to the door, so I just knock on it and he lets me in.

His setup is similar to mine, but his bed is raised, so I sit on the bed while he’s programming and when he cocks up, I tell him what he’s doing wrong. I try not to tell him exactly what he’s done wrong; I just say ‘Look at that. What do you think is wrong?’ If he doesn’t get it after two/three minutes, I tell him.”

Interviewer: “How often have you gone around to his?”

Thomas: “It’s happened twice this term, but generally it happens when there’s class assessments that are set and he hasn’t finished them in time. He’s got stuck, because obviously, he can’t... Well, he could send an e-mail, I guess, to his programming seminar leader, but he doesn’t. So, I come around and help him.”

In this excerpt, Thomas describes going to Toby’s study bedroom to help him with his classwork and indicates that this happens when Toby gets stuck with his work.

What stands out is how Thomas begins to say Toby couldn’t email his class supervisor for help (for some reason), but corrects himself that Toby could, but chooses not to. This provides us not only with a glimpse of peer-instruction taking place in the first term of the undergraduate programme, but also a recognition that other help is available; however, at this stage they choose not to use it.

Percy also reported a similar experience of help-seeking / help-providing occurring amongst his group of friends:

Percy: *“We went to Gordon’s room. We ended up doing the People and Computing work, and after that, me and Gordon we just generally chatting. That’s when Oliver asked about coding, and that’s when I helped him, although I’ve helped him several times before on coding. But I only helped him in person because of the convenience, because he and I happened to be there together. If we hadn’t had been there on that same day, I probably would have still ended up helping him, because he seems to ask me quite a bit, but it would have been over the phone or text.”*

Whilst Percy reports helping Oliver with his coding, and that this was not an isolated occurrence, Percy helps Oliver in this space because of convenience (they were already working together in Gordon’s room).

My Programming Week Interview Transcripts – Second-year Undergraduate Students

So far, the use of virtual spaces to support academic study appears to be limited; in the first diary study, we encountered only a few instances of students using online sites, such as Facebook. However, in one of the second-year My Programming Week interviews, Renly characterized his use of Facebook groups:

Renly: *“I think it's just because Facebook is open and, if nothing else, it's just lazy. It's laziness because Facebook is open and I can go and post on there straight-away... More people are going to be on Facebook, because most people have Facebook open all the time or they visit each day.”*

In contrast with the spaces we have described thus far, Renly characterizes Facebook as less of a space where students go, and more of a place where students are.

Renly: *“...especially, Tom and his own little group, I see as a huge knowledge base because there are a lot of people from lots of different generations who will have used lots of different programming languages and been thinking in lots of different ways. So, you can, basically, ask all those people and have all that knowledge pouring into your problem. For both personal and*

University work, it's a great resource to have because there are so many [people] knowing so many different things... So, if you want to ask a 'C' question, which I did with the operating system stuff, you can: and I got two people who knew exactly what I was doing wrong”

Renly goes further and suggests that for these groups, how a person interacts with them is important:

Renly: “I'll often just try and look for one feature I'm having trouble with and then create a very generic question. That improves my knowledge more widely.”

This suggests that although Facebook is a space where students ‘always are’, its use is not indiscriminate; students go to different groups to seek specific kinds of help and specifically frame their questions for the kind of help that they would like to receive. This suggests, that some of the features of ‘place’ that we have discussed about physical spaces, also potentially exist in Virtual Spaces.

Facebook was not the only virtual space that second-year students identified using to support their academic study. Another participant, Jamie, describes his use of Internet Relay Chat (IRC):

Jamie: “Actually, I was on the Haskell IRC channel on Freenode, and I said, ‘How can I display precedence for certain operators?’ They directed me to the source code for the ‘Show’ function in the Haskell source code, which actually showed me how I can write a function that works in the way I wanted...Even if it was simple things like troubleshooting, for example, I am running Debian and there is an error or something. I can go to the Debian IRC channel, and just pop on there, and ask people questions.”

For Jamie, rather than going to Facebook to consult his peers, he chooses to solicit help from the developers (experts) of the Haskell programming language and the Debian operating system, by going to a space he knows he can find them (IRC).

The Peter Brown Room

A space that stood out from the diary entries of the second-year My Programming Week participants was the Peter Brown Room. As already described, this is a computer room available exclusively to students of the School of Computing. Although this room is available to all School of Computing undergraduate students, it did not appear in any of the diary entries of the first-year; in contrast, this room was the only formal space, that appeared in the second-year diary entries.

One of the second-year participants, Jamie, described in his interview the kind of activity that occurs in the room:

Jamie: *“For example, a common thing is I am talking with one of my friends about the assessment. [Someone will] overhear that we are doing it, and say, ‘Oh, yes, I am struggling with that’, and then I will help them.”*

Another second-year participant, Cersei, reported similar experiences:

Cersei: *“It's mainly when I'm in the Peter Brown Room, when other people are working on the same assessments as I am [that] we end up talking about it. We might be working on something and someone's like, I see you're working on this project, what are your ideas on this?”*

Cersei suggested that she felt a responsibility to help people in this room if they asked her for help:

Cersei: *“If people ask me for help, I help them because I feel bad if they don't know what they are doing.”*

Jamie expressed a similar commitment when he went to the room:

Jamie: *“I usually go once or twice a week. Sometimes I will just go in there on my own, and not be expecting to do anything, or*

sometimes I will actually go there with an intention to help people, or work on an assignment.”

This suggests that students go to the Peter Brown Room not only to find help for their own problems, but also to help their peers. Jamie expanded upon this and suggested that he found it personally motivating when people finally solved their problems with his help:

Jamie: “Recently I helped somebody understand algebraic data types in Haskell. I was drawing that on the whiteboard, like describing things, and writing out the types, and rubbing out bits, and things like that. After about half an hour or 40 minutes, he hit the epiphany point. He was like, ‘Oh, I get it now.’ That was just really enjoyable actually.”

Supporting other students in the room is not a one-way interaction, and Jamie suggests that helping other students with their problems is mutually beneficial:

Jamie: “Even if I am not necessarily struggling with an issue, I will go up to the Peter Brown Room..., I can bounce ideas off them, whilst trying to solve their problem.”

The interview transcripts demonstrate that the second-year students clearly expect, in this space, to talk with each other, work together, and help each other out. In this they are not seeking direct help or ready-made answers, behaviour that LeGall describes as “executive help-seeking” (Nelson-Le Gall and Glor-Scheib 1983); but instead are demonstrating considerable mastery of “instrumental” behaviours:

“Instrumental help-seeking ... refers to those instances in which the help requested appears to be focused on acquiring successful processes of problem solution and is limited to the amount and type needed to allow learners to solve problems or attain goals for themselves... Learners with effective instrumental help-seeking skills are able to refuse help when they perform a task by themselves, yet they can obtain help when it is needed” (Gall 1985, p.67)

It is also a space that is currently unused by the first-year students although it is visible to them. The community that exists within the Peter Brown Room, one of mutual sharing of knowledge and support, is something that the first-years have yet to engage with; this suggests that the first-years are literally and spatially on the edge of our community. It is only as they progress within our course do they see the spaces that other computing students inhabit and begin to participate in them as well.

2.4 Conclusions

As we see in the literature, spaces are physical, places are human (Tuan 1977; Harrison and Dourish 1996). Several places may be present in a single space and “work” is not confined to the spaces that are pre-allocated for it; that is, whilst we can design space to afford particular kinds of activity, the use of space ultimately depends on the individual(s) who inhabit it (Harrison and Dourish 1996).

These theoretical constructs are represented in our data. Both first- and second-year students use a variety of spaces on campus for academic work: some of them formal spaces, used outside of scheduled time; some of them domestic spaces (study bedrooms); some of them third spaces (cafés and bars).

There is also a striking difference between the first- and second-year usage.

Domestic spaces aside, first-years use formal spaces that are visible to them – the Library, rooms they have been taught in, cafés. These are all spaces that the University purposefully makes students aware of: they’re listed on timetables, are shown on open days, helpers guide the way to them during the first weeks of term, and they appear on campus maps online.

Second-years use spaces that are not immediately obvious; for example, the Common Room and the Peter Brown Room. Unlike the spaces described above, we don't direct our students to them. This indicates growth of community and "insider knowledge", as students come to find out about these spaces during their first-year and observe the kinds of activities that take place in them, they begin to participate in them.

We also observe a transformative property of space and place, with students transitioning between them as their understanding of different spaces develop. This supports Erikson's suggestion that spaces do not automatically become 'places' from their outset and individuals conceptualize places differently - the same space can function as different places at different times, with no change to the physical environment or layout.

In response to research question one *what spaces do computing students utilize outside of formal activity*, the contributions of this study towards this thesis are:

- We have developed an instrument that can help us capture the use of physical space by computing students.
- We have presented a number of ways to visualize the data to help the reader and researcher to understand it.
- We have identified a number of different kinds of spaces that are present at our institution and have mapped their use to existing literature.
- The individuals that go to these spaces have expressed, in their own words, **why** they go to particular kinds of spaces rather than others. These reasons

include (but are not limited to): a common distance between participants, a ‘neutral’ ground for work, common access, and anticipation to find others there.

- We show that students choose to use different spaces (and different patterns of spaces) as they become more knowledgeable members of the computing student community, “seeing” spaces that were previously invisible, and using them as sites of disciplinary practice.

Chapter 3 - What are the practices that students engage with when they are studying computer science?

3.1 A Consideration of Practice

In the introduction to this thesis, we presented a number of different works that demonstrated the complex inter-twining of space and practice (Orr 1996; Nespor 1994; Rose 2005). Similarly, in our first study, we encountered at times a bi-directional relationship between space and practice – there were instances where student practice was influenced by the spaces available to them, and at other times, student practice influenced the use of space. Boys (Boddington and Boys 2011) suggests that “material space should not be understood as directly reflecting the social life it contains, but as the uneven patterning between/across various attempts to ‘make concrete’ specific social practices rather than others...” (Boddington and Boys 2011, p.60). Study one informed us to the ecology of spaces that students use outside of formal study, as such the goal of study two is to identify the practices of computing that students engage with beyond the academic classroom.

Practice encompasses a wide variety of different theoretical and methodological approaches that may be broadly distinguished into two waves: the first generation of practice theories developed by Bourdieu, Giddens, and Lave and Wenger (Bourdieu and Nice 1977; Giddens and Turner 1988; Wenger 2000) provided the foundation for a second generation of works by Reckwitz, Shove et al., Kemmis, Schatzki and others (Reckwitz and Black 2017; Shove and Spurling 2013; Kemmis 1992; Schatzki 2001). There have also been efforts in related fields that have influenced practice theories, such as discourse analysis, participant observation, ethnomethodology and actor network theory (Brown and Yule 1983; Cushing 1882; Garfinkel 2005;

Murdoch 1998). Regardless of the specific theory of practice that a researcher adopts, a practice perspective has several advantages:

- Practice theories incorporate physical objects, such as materials and the body. Viewed as a practice, learning and education are not just about individuals' cognitive ability and the acquisition of content knowledge.
- Practice theories adopt a processual perspective and shift the attention from the individual or the organization to practices as the focus of inquiry and key unit of analysis. So, *programming, being a student, or becoming a software professional* may all be examined as practices.
- A practice lens permits the exploration of interlocking practices. As Gherardi writes, "one of the greatest theoretical and methodological opportunities offered by the concept of practice resides in the fact that practices rest on other practices: that is, they are interconnected and their interconnection makes it possible to shift the analysis from a practice to a field of practices which contains it, and vice versa." (Gherardi 2013, p.155)

In this research, we draw on a framework developed by Shove et al. (Shove and Spurling 2013) that defines practices as consisting of three inter-relating elements: *materials, competence, and meaning*. This is a deliberately sparse construction. Shove and colleagues sacrifice richness for utility, as they believe many other practice theories, whilst influential, (Giddens, Schatzki, Reckwitz) are effectively un-implementable; the limitations of Giddens' approach in particular have been identified in relation to empirical work, as Giddens did not develop a methodology

to operationalise his theory, which has a limited role for objects and artefacts (Roberts 2014).

Looking at students with this practice lens brings different things into focus. For University students encountering the practice of computing, *materials* comprise the coursework, curriculum, IDEs etc., but also spaces to work in and the facilities they offer. *Competence* includes straightforward academic achievement, but also common interests and skills (BCS Chapter meetings, TinkerSoc – a student maker society predominantly comprised of Kent computing students). *Meaning* is made up of many pieces, only a few of which are under direct control, at global levels there are figures, such as Bill Gates, Larry Page and Sergey Brin, press stories of misogyny in Silicon Valley, such as driverless cars and autonomous drones. At personal levels there is contact with friends and relatives who work in the industry; and at local levels, there is the experience of studying computer science at Kent, with 150 other students in the cohort.

3.2 The Critical Incident Technique

For this chapter, we used a set of pre-existing interview transcripts and conducted an analysis inspired by grounded theory to develop a coding scheme that identifies some specific practices that students engage with. The data was gathered using a protocol adapted from one devised by Judith J. Lambrecht (Lambrecht 2000) to investigate the development of computing literacy skills and which belongs to a tradition of investigation called *Critical Incident Technique* (Flanagan 1954).

The Critical Incident Technique (CIT), was originally devised by John C. Flanagan to create a “functional description of activity in terms of specific behaviours” to “increase the usefulness of the data while sacrificing as little as possible of their comprehensiveness, specificity, and validity” (Flanagan 1954, p.19). It is applicable to many domains and has been used widely, from studies to identify effective and ineffective work behaviours of United States Army Air Force pilots (Flanagan 1947), to investigations of health and safety issues (HSE 2009), and to education (Corbally 1956). Its defining feature is that it focusses on the recollection of a ‘critical incident’ - an event that encompasses “... extreme behaviour, either outstandingly effective or ineffective with respect to attaining the general aims of the activity.” Flanagan considered extreme nature to be an important aspect; as such, events “can be more accurately identified than behaviour which is more nearly average in character.” (Flanagan 1954, p.12)

From the outside many critical incidents appear at first glance to be commonplace events; however, it is the importance that the *participant* attributes to the incident and its transformative effect on their understanding and practice that makes it “critical”. For us, the nature of a ‘critical incident’ makes this technique attractive as a focus for research that attempts to identify experiences of profound moments of learning.

Going beyond the simple identification of an incident, the structure of CIT protocols attempts to develop an objective description of an incident from the perspective of the person who had the experience, and whilst there are many methods to collect CIT data, interviews are commonly used. CIT protocols follow a common pattern. First, a

framing question is posed to the participant to identify a suitable ‘incident’ for the researcher’s needs. The framing question, from Flanagan’s perspective, is one of the most important parts to get right as it can dramatically influence the kind of response retrieved by an interview participant. The interviewer then attempts to develop an overview of the incident in question; the cause, the key events that occurred and the final outcome. This develops a chronological *timeline* of the event, which provides a shared reference for both the interviewer and participant. It also aids the participant’s memory. Once this timeline has been developed, the discussion moves to the participant’s activity during the incident. The interviewer enquires about the participant’s emotions and their perceptions of the event as it unfolded. The participant’s reasoning for why they think certain aspects of the event happened are also probed at this stage. It is this step which provides thick description and detail about the incident, from the perspective of the participant. CIT traditionally focuses on developing objective descriptions to support generalizations of work practice; however, over time, the method has evolved towards the participant being encouraged during the interview to provide their own personal opinions and suggestions - reflecting on the incident and the personal significance that it had on them.

3.3 Programming Practice Study

The idea that disciplines have “threshold” concepts was first proposed by Erik Meyer and Ray Land in (Meyer and Land 2003). When compared with other kinds of concepts, threshold concepts are identified as having certain characteristics: they are held to be *transformative*, *irreversible* and *integrative*; that is, once understood, acquisition of a threshold concept creates a significant shift in perception that is

unlikely to be forgotten and which exposes previously hidden interrelatedness with other concepts.

Threshold concepts differentiate between “core learning outcomes that represent ‘seeing things in a new way’ and those that do not” (Meyer & Land, 2003). For example, “gravity” has been proposed as a threshold concept in the learning of Physics (Meyer, Land and Baillie 2006; Meyer, Land and Baillie 2010); “opportunity cost” in Economics (Shanahan 2016); “state” in Computer Science (Shinners-Kennedy 2008) and so on.

For some, acquiring a threshold concept may be easily accomplished, but for many students they are a point of difficulty. Researchers have described the stage of acquisition as one of *liminality*. “Difficulty in understanding threshold concepts may leave the learner in a state of ‘liminality’, a suspended state of partial understanding, or ‘stuck place’, in which understanding approximates to a kind of ‘mimicry’ or lack of authenticity.” (Land, Meyer and Baillie, 2010). Cousins (2006) likens this to the world “which adolescents inhabit: - not yet adults; not quite children. It is an unstable space in which the learner may oscillate between old and emergent understandings just as adolescents often move between adult-like and child-like responses to their transitional status.”

These liminal stages in which students are stuck, where they realize that there is something important to be learned (about gravity, or state) but have not yet achieved understanding, would seem to be fruitful ‘hunting grounds’ for threshold concepts.

In 2007, Shinnars-Kennedy and Fincher, carried out an interview study with twenty-nine undergraduate students from three UK universities to identify, and investigate the properties of, threshold concepts in computer science. In doing so, they focused on liminal stages. In particular, they asked students to recall times when they became “unstuck”, when they finally understood a troublesome concept. The framing question for the study was:

“I want you to think of an occasion when you finally caught onto a concept that you were having a hard time understanding. This might be an occasion when you were in a computing class, private study or interacting with other students in your course. Describe the key elements of the activities that caused this noticeable impact on your learning and understanding.

If possible, can you provide enough detail so that the effect can be clearly understood by others?

I may ask you some questions to assist you with telling your story.”

This framing question was supported by a number of prompts that were used to elicit more detail:

“Why do you think it was a problem for you?

What do you think you were lacking or might have been missing that caused it to be a problem?

What do you think helped you to move from being troubled by it to feeling you understood it?

When you felt you understood - how did you know?

When you understood, did it change the way you viewed things afterwards?

If you were trying to describe it to someone now, what would you do so that they would avoid having the same difficulty?”

(Shinnars-Kennedy and Fincher 2013)

The interviews were professionally transcribed, recordings destroyed, and subsequently the corpus was made available to the Computing Education Research Group at the University of Kent. For details of the initial study, see (Shinners-Kennedy and Fincher 2013).

This corpus was appropriate for, and attractive to, this research for a number of reasons:

- The data was collected by a researcher who was independent of our own research. This would help mitigate potential researcher-bias introduced in the first study.
- The interview cohort comprised second- and final-year computer science students from three different UK higher-education institutions. By using this dataset, we are able to guard against programming practices that may be idiosyncratic to single institutions.
- We hoped that the data would be a fruitful site of practice. Learning is hard to observe when things go “right”, so by using a dataset that focused on sites of difficulty/moments of insight, we hoped it would foreground the sort of material we sought.

We considered the “stuckness” that framed the incidents to be a useful lens with which to explore students’ programming practice, because it represents precisely the point in a person's learning where a deficiency in their own knowledge prevents them from continuing further with their work and, as such, they have to reach beyond their own resources. The corpus lends itself well to the purposes of this

study, because the practices that the students describe come from real moments of difficulty when learning to program, rather than an artificial and constrained task.

CIT is not only a technique for gathering data, but also for analysis. This generally follows a two-stage process. As Flanagan specifies, “The first of these two other steps consist of the classification of the critical incidents. In the absence of an adequate theory of human behaviour, this step is usually an inductive one and is relatively subjective. Once a classification system has been developed for any given type of critical incidents, a fairly satisfactory degree of objectivity can be achieved in placing the incidents in the defined categories.” (Flanagan 1954, p.9). We will present the classification resulting from the CIT data in the remainder of this chapter.

3.4 Grounded Theory

Whilst Flanagan has a lot to say about the methods and procedures for collecting CIT data, he has less to say about how to conduct the analysis and then present the data to others. Grounded Theory, by Glaser and Strauss (Glaser and Strauss 2009) is a systematic approach for developing theories that are grounded in data; that is, collecting data and *then* developing a theory, as opposed to the traditional ‘scientific method’ of defining a hypothesis and then using data to test its validity. When fully used, data collection and analysis go hand in hand – as themes begin to emerge from a qualitative dataset, additional data is collected and analysed to attempt to validate the themes that are being uncovered. Grounded Theory could have been used as a framework for conducting the whole research; however, as we already had a dataset that we wish to analyse, we used the principles of a grounded theory analysis to develop a “classification system” from our corpus.

3.5 Programming Practice Analysis

In a Grounded Theory approach the texts are read (and re-read) to discover themes and their interrelationships (Charmaz 2006). For the ‘first sweep’ of the data, each interview transcript was open-coded to identify key points and areas of interest; these were identified with a *descriptive anchor* – a phrase which captured and identified the essence of the practice so that it could be referred to on subsequent occasions. This purposefully undirected examination was used to sensitise the researcher to the data, which was initially surprising. Students often struggled to precisely identify incidents that had a ‘noticeable impact’ on their learning. Typical responses showed a lack of ability to pinpoint a specific moment in the continuous activity of learning:

Angelina: *“I don’t know, thinking of **one** occasion? I’m really having trouble with [this], actually, because it was just a kind of ‘Oh, I didn’t know it’: and then I learned it.”*

and a retrospective lack of comprehension of the original problem

Irvin: *“I mean it’s quite difficult to look back now and see why you’d have trouble with that—because obviously, it’s quite easy. I don’t know.”*

However, despite the lack of “extreme” recall participants were at the same time able to recall quite accurately the activities that surrounded these incidents; incidents that had on some occasions occurred months/years before the interviews. Although seemingly paradoxical, it has been observed “It is strange how, in an unhappy or happy experience, one remembers vividly the details of one’s surroundings and little, unimportant happenings” (Westfeldt and Matthias 1998, p.86)

Sometimes these recollections included considerable depth, with students being able to describe clearly *who* they were working with at the time, *what* they were working on and *how* they attempted to resolve their problems

Who –

Henry: *“Steve showed it to me;”*

Rebecca: *“My brother helped me a lot figuring out how to work with pointers”.*

What –

Steve: *“He started writing a program to create a stack”;*

Frank: *“we’d be having coffee and I’d go. ‘oh, James I’m curious why’ ...”;*

Sam: *“We had a lab session and we were kinda working in pairs. I was working with my friend, Rob, just going through stuff and I kept getting compiler errors”.*

How –

Henry: *“You try something – it doesn’t work, you try something else. There are plenty of efforts at trying to make things work for the project and it didn’t work. So, try something else. Try it some other way.”;*

Eugene: *“I actually only got it after seeing this graph, which was moving, so I saw what was going on with most of the data.”;*

Clark: *“Drawing out the box and then going through this on pieces of paper”;*

Philip: *“I saved the sample code and instead of sitting down and writing the code myself, I would just plan and use this code and just keep reusing the code that we were given, which was fine at first”.*

Several passes of the entire corpus were performed, using the software package

NVivo, each time creating and refining new codes – identifying anchors that allow

the descriptive anchors of the data to be gathered, appending annotations, marking interesting areas of text or relating themes with interview scripts. At this phase (called “axial coding” in grounded theory), some “obvious” clusters of practice emerged, often closely related to existing classroom behaviours or observed student interaction. An example of the former would be:

Calvin: *“I got through recursion by staying a bit longer with the teacher”.*

For the latter, sometimes they refer to behaviours that we would expect, or encourage:

Austin: *“If there’s a keyword that I don’t understand, I’ll go and look it up”.*

Other times to wider, social, resources:

Clark: *“Someone sitting down with me and saying ‘OK. This is how it’s done”.*

For the next phase, the work was exported from NVivo to a physical document, separating the codes (425 in total) and the descriptive anchors from the interview transcripts. Two researchers collaboratively discussed the report, merged similar codes under a single heading, identified themes and started to develop categories. The examples that follow illustrate some of the codes and themes that were developed at this stage - it does not represent a complete list, nor the final coding scheme (which will be presented later). At this stage, themes emerged that clearly expressed the community (and community interactions) anticipated by the studies in the previous section. These concerned students reaching out to others in the community (co-located or remote) for help, mobilising community resources for their need:

Code	Number of Interview Transcripts that Contained the Code
Reaching out to others in the Community (Co-Located)	14
Interaction with the Compiler (Personified)	7
Reaching out to others in the Community (Remote-Located)	3

Table 2: Excerpt from collaborative discussion 1

- **Examples of Reaching out to others in the Community (Co-Located):**

Henry: *“Well generally, he’d whip up the program and go, ‘that’s how you do it’. I suppose he just dumbed it down to an extent... it’s easier for me to talk to him cause he’s a friend. So if I get angry, it doesn’t matter. I don’t get nervous or anything like that.”;*

Stanley: *“One of my housemates in the first year, I spent a lot of time going through some real simple Java stuff with him.”;*

Sam: *“He was comparing what he’d done to what I’d done and he was just kinda showing me where I’d gone wrong”;*

Frank: *“It was working with that guy in almost kind of an apprenticeship sort of situation where he was just guiding me through it. I was, you know, under the wing of an expert”.*

- **Example of Interaction with the Compiler (Personified):**

Wilbert: *“It’s just some of the things it comes out with. Sometimes obviously, it goes ‘I was expecting a colon, but it didn’t come’ and you think, ‘oh bloody hell, I’ll put a colon in’. But sometimes it can just come up with something and, again, these horrible words, ‘instances’ and ‘classes’ and ‘methods’, pop up and I just think, ‘I have no idea what you’re about’.*

- **Example of Reaching out to others in the Community (Remote-Located):**

Roy: *“Asking on forums and stuff like that. If you have a really difficult problem, you just basically type in your code. Look, I’m having this problem. My code won’t work. Why? Some guy will come back to you in a couple hours, and he’ll let you, oh, it’s just so and so, and they’re all very helpful.”*

Identification of these categories also illuminated community boundaries – it’s OK to reach out, in some cases it is inside (or you are part of) that community; however, there were also categories which were not community-based. Some of these are closely characterised by the *materiality* of practice the materials that formal learning involves:

Code	Number of Interview Transcripts that Contained the Code
Use of Textbooks	6
Use of Notes	4

Table 3: Excerpt from collaborative discussion 2

- **Examples of using Textbooks:**

Aaron: *“I just happened to be flipping through the book when he was explaining things to me and there were examples in the book which just kind of broke everything down into a simple program – very simple program into three or four separate classes. All of them had interaction through another class and the second I was reading through it a very simple example it just immediately clicked with me after having tried to study for so long. So I think it was just kind of a buildup and then eventually the barrier just broke or something.”;*

Erica: *“I was looking at Java books to see how they’d used them and what examples they have of using one rather than the other and working out which one’s the best one to use in the situation.”;*

Stanley: *“The text book, which I didn’t buy but I did read for a little bit, was quite clear and gave an introduction into how you can start thinking about things in an object-oriented way.”.*

- **Examples of using Notes:**

Roy: *“And when I saw some of her notes and stuff, they remind me an awful lot of the notes that I got in first year when I was learning C++”;*

Jerimiah: “so, I was – I would just look back through the notes for a section how to create a class and then copy and change it to my needs”.

These exemplify how materials are linked to practice: you use the textbook you have to hand (that has been recommended), the notes that have been provided.

Other themes emphasised students’ disciplinary *competence* and their growing relationship with coding and debugging, from naïve to sophisticated. It is in the nature of a practice that a practitioner’s relationship to materials changes as their expertise increases. So a student will have a different relationship to code when they are at school using Scratch, when at university using BlueJ and when at work using Eclipse.

Code	Number of Interview Transcripts that Contained the Code
Stepping Through the Program	7
Trial and Error Coding	5
Using a Piece of Code to get by	4
Taking Apart Pieces of Working Code to Understand its Operation	2

Table 4: Excerpt from collaborative discussion 3

- **Examples of Stepping Through the Program:**

Henry: “Whereas, I can if I’ve got working code, I can press F7 and follow the calls through. Method to method and class to class. And that makes it a lot easier. That’s one of the main things he’s done. When he’s explaining stuff – and I suppose you can say he does it recursively. He keeps going ‘til I understand it. That’s kind of a get out of it kind of answer.”;

Susie: “I have it printing output ever so often until I see that what I put is printing is wrong and then I know that it’s between the last correct output and this output that there must be an error.”.

- **Examples of Trial and Error Coding:**

Calvin: *“I found during first semester the questions were quite complex and really the only way to go was to take one method, write it out and see how many errors you get and then work out those errors. See what the output is and then see that it is wrong and go back.”*;

Stanley: *“Whereas Java you can just run it and compile it and see what happens and maybe you get an exception and you try again.”*

- **Examples of Using Pieces of Code to get by:**

Jerimiah: *“You don’t care about what you’re learning from it, so much as you get a working program, so I was – I would just look back through the notes for a section how to create a class and then copy and change it to my needs rather than trying to understand the course really.”*;

Angelina: *“So, someone would show me something and I’d pretty much use what they give me, and didn’t really make the connection of how it really worked until a few months ago.”*;

- **Example of Taking Apart Pieces of Working Code to Understand its**

Operation:

Ernest: *“I basically just look at my friends’ programs and things and saw that they were kind of the same, but written in a completely different way. I could tell what each part was doing and how it was then working together, it really helped make me see what steps I needed to take.”*

Some of this competence was not related to the practices of computing specifically, but to general life skills which they applied to their practice:

Code	Number of Interview Transcripts that Contained the Code
Search using Google	2
Browsing the Web for Answers	8

Table 5: Excerpt from collaborative discussion 4

- **Example of Using a Search with Google:**

Roy: *“But then, if you're only beginning and you're trying to understand the concepts, then Google is just as well of a great place. There's so many beginning tutorials on each individual concept, and they help you as well.”*

- **Example of Browsing the Web for Answers:**

Larry: *“I would still read little articles on their Web site once in a while and reading these articles and examples of how to do things, it suddenly occurred to me, oh, I was layering all this extra stuff – functionality – around the system when I should have just been using the system because it already had this.”*;

Finally, there was a theme that drew together competence and meaning. There was a collection of responses from students who declined a disciplinary identity, whether because they had “learned” they weren’t productive (or, not learned the material presented) so their competence was compromised. They constituted their meaning within the community differently and described their activity in terms other than programming.

Code	Number of Interview Transcripts that Contained the Code
Avoiding Programming	4

Table 6: Excerpt from collaborative discussion 5

- **Examples of Avoiding Programming:**

Frank: *“If I didn’t know how to do it, it was his job to fix that for me. It came to the programming guy”;*

Tanya: *“It’s really focusing on what I know I could be better at easier. With less effort, I can do a report on systems analysis and whatnot and human-computer interaction”;*

Angelina: *“So, I never really sorted of looked at it and just worked how it was working and stuff. I think I always assumed it was a lot more complicated than it was, so I didn’t want to put in the effort of working at it.”*

Although this didn’t seem to “fit” we embraced the data and in the qualitative tradition, included the category.

3.6 Presentation of Findings

The coding scheme was then reapplied to the transcripts and refined during each pass; new themes were identified, codes were consolidated and on some occasions, removed. We chose to model our presentation on a coding manual developed by Amabile (Amabile and Kramer 2011). Her research was concerned with “identifying events that impact the work environment, motivation and other aspects of daily experience, and creativity (as well as other outcomes) in both positive and negative directions” and as part of this work, she developed a comprehensive coding manual

to “serve as a guide for other researchers who wish to adopt a methodology similar to ours” (Amabile *et al.* 2003, p.3). Her coding manual describes how to capture and present the essence of important events from her data, which was free-text diaries and transcripts of observation sessions; data that is similar to our own. We adopted a similar structure of her coding scheme table to present our findings.

Amabile’s coding scheme table incorporates the following definitions:

Code: Numeric codes that correspond to a list of event types. For example, ‘Code 2070 is “Compromise / Bargain”.

Event Type: A short descriptor of “what happened”.

Definition: The definition of a category (the current row in the coding scheme) and the coder’s primary guide to choosing if it applies to a segment of text being coded.

Description and Examples: Intended to help coders better understand each category.

The table, Table 7, provides an example of a completed row in her coding scheme table (Amabile *et al.* 2003, p.7):

Code	Event Type	Definition	Examples & Description
The Work / Project			
1000	Cognitive Event	Thought process or the outcome of a thought process; report of any thinking, insight, realization, idea, learning or understanding...	A cognition, thought process, or idea must be mentioned. People often used the phrase “I learned from that” or “I found that”

Table 7: Excerpt from Amabile's Coding Table

For our work, we made alterations to the structure of the table. The first is that we use a textual, rather than a numeric, indicator within our ‘Code’ column. This was because in our grounded theory analysis we only ever assigned a single code to the descriptive anchors, whereas Amabile’s version supports multiple numeric codes for a given event. The second difference is that we split the ‘Example/Description’ column in Amabile’s table into two separate columns; the ‘Examples’ column now provides a canonical example and the ‘Description’ column now provides guidance of when to apply the code.

The next 14 pages contain the coding scheme that was developed from the Grounded Theory analysis of the twenty-nine interview transcripts. It is presented in similar format as Amabile’s coding table: terms used and structure are presented first, followed by the complete coding scheme. In presenting our grounded theory analysis

earlier, we showed the count of the number of occurrences of the application of each code (to support our analysis), the structure of the coding scheme here does *not* include a sense of hierarchy or frequency – like Amabile we intend this coding scheme to be of use to other researchers as an instrument for analysis of qualitative data, and as such we do not want to influence subsequent analysis.

3.7 Coding Scheme

Terms

Type -- The overarching categories that were developed.

Code -- The descriptive label to use when coding the transcripts.

Definition -- A short description of the label.

Description -- An extended description explaining how we interpret the definition.

Example -- A canonical example from the interview transcripts.

Structure

These are the main themes of our coding scheme:

1. Programming Practices
2. Changing Representation
3. Deliberate 'Pedagogical' Practices
4. 'Non-Pedagogical' Practices
5. Social Public (S.O.S)
6. Social Private

Visualization of themes

To assist the reader, we have mapped our coding scheme's themes to an alternative visualization (Figure 20). This visualization is informed by similar methods from social geography. Personal practices are within our immediate 'sphere' of influence and because of this, are located at the center of our diagram. Deliberate Pedagogical and Non-Pedagogical practices (e.g. books, lecture notes and google) still only require the individual to interact with them, but the content is provided by others.

Finally, social private practices, require us to interact with others; as such, they are located on the edge of our diagram.

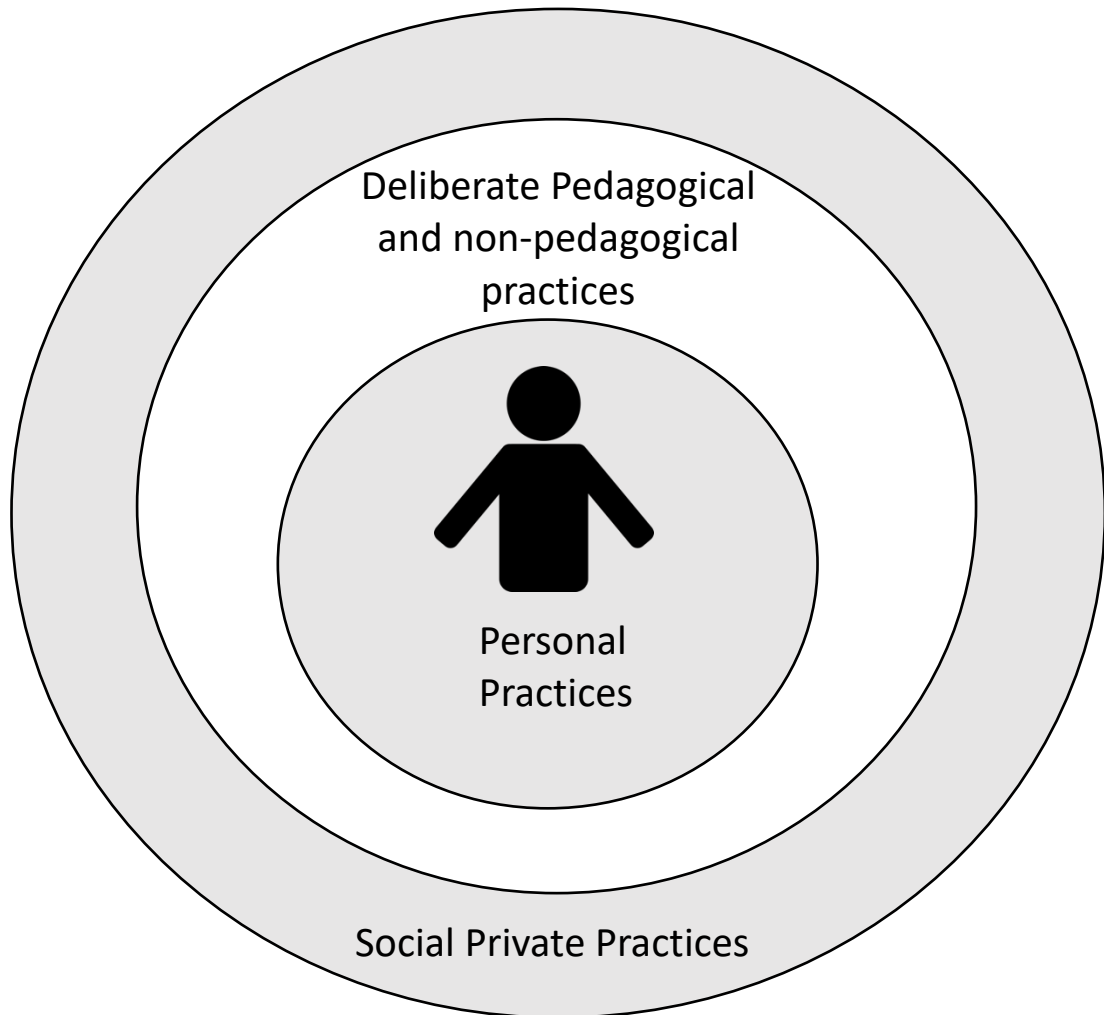


Figure 20: 'Personal Space' Diagram

Programming Practices

Type	Code	Definition	Description	Example(s)
Personal Practices				
	Mimicry	Using existing examples as a framework	When a student describes using existing materials as a framework for structuring their own work. There should be a sense that the example is being used just as a 'scaffold'.	"I would find myself copy and pasting and then changing that to the extent that I take away all the text but leave any brackets and leave the commas, but having that guideline, having those brackets and the commas, knowing I'm gonna type this in and then, that makes sense."
	Borrowing a code fragment	Using a piece of someone else's code	Disclaimer: This code is not for acts of deliberate deception (plagiarism)! Instead, it is for when a student describes the use of someone else's code in their own work to get them by (e.g a shim). Look for a lack of understanding as to how it works ('blackbox', taken on trust that it works).	"I had to you know copy other people's work and put things in to understand it so and so forth and I really scraped through the first couple of years of the program in using pointers because of this."

	Taking it Apart	‘Dismantling’ existing code to see how it works	Deliberately modifying values or the removing lines of code and then observing the effect it has on the entire program. There should be a sense that the person is trying to understand how the program is working by ‘tweaking’ (don’t use this code if they are just adding things like print statements – use ‘stepping through’ instead).	“I’d start pulling bits out of it and see if it still works and see what impact it has if I don’t really understand it and stuff like that.”
	Stepping Through	Observing the function of the program at each step	When the student is trying to ‘see’ the program running and the changes that happen at each execution step. This could be through the use of a debugger, but program modifications such as adding print statements are allowed.	“I just went on a Web site, looked at the code, took a small sample of the set of data, plug it in, and just trace it.”
	Scaffolded stepping-through	Observing the function of the program at each step, directed by an external source	Same as the above description (stepping through), however, use this code if an external source is directing the student. There is a sense that the student is being informed as to what is happening at each step of the program, rather than independent discovery. For example, stepping through an example program line by line, but	“So take for example, for that pop-up box, they’re like, they’d explain it fully, they’d walk through the code, and they go, to download the source for this project, you run it, you see it implemented. You open up the code, you look to see what’s happening, and you understand what’s going on.”

			using a provided explanation from a tutorial or whilst the class supervisor speaking, in order to understand what is happening at each step.	
	Shotgun Debugging	'Blindly' trying solutions	A ' non-diagnostic ' approach is used to try and debug a problem. There may be a sense that the student is just responding to the suggestions by the compiler, without understanding whether it would resolve the problem and (if it does) why it was successful.	"I don't – I can't understand that. So I'll look through it and try my luck and tweak a few things add a void, add a public, or change it to a private and with enough tweaking, eventually it works, but some of the words that the compiler can come out with, you just – hm."

Changing Representation	Code	Definition	Description	Example
	Visual	A visual representation (i.e. diagram) of the program / problem.	Use this code when a uses a visual representation. This does not need to be a physical object with pen and paper, but can be a mental representation.	“I think to myself, ‘Right. I need this to do this,’ it’s straightaway it needs paper and pen. It needs squares and circles and I guess in some ways when I think about something that has to be done, I think in terms of squares and circles but once I’ve drawn my squares and circles then I recognize them as methods and classes and this and that, but I guess that link between thinking what I want to do and turning that into methods and classes needs for me that step in the middle of drawing diagrams.” – *adopted this practice following the suggestion from a supervisor*
	Terminology	Changing the terminology to something they understand / relate to	Changing the terminology used. For example, describing the problem in ‘Plain English’.	“I think the only coding I’d ever done before coming to university was just in Visual Basic for applications, not even the full Visual Basic, just if I was in Access and I wanted to write a posh macro rather than record it, I’d write it myself and

				<p>Access is very, very straightforward. It's "You do this; you do that" using sensible English and _____ I think I've got it right there. Using English that makes sense, you do this, you do that. You call things what you want. You don't have to say public void."</p>
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Type	Code	Description	Example
Deliberate 'Pedagogical' Practices (Contemporaneous)			
	Books	This category is for books that are used to support academic study.	"If I didn't pick it up, say, within three to four hours, I would then go looking through books. I bought a ton of computer books and I read a ton of computer books on different concepts and how to apply them."
	Guidance Notes	This category is for the formal notes provided by a lecturer / supervisor (not personal notes created by a student).	"We were given a very useful guide sheet – it was the very basics one – I found that I would often copy the first line."
	Slides	How slides (e.g lecture + supplemental) are used by students.	"I had the slides in front of me. As he [the supervisor] was talking about them, I was reading through the slides, and working it out in my head."
	Analogies	This category is for the use of analogies when explaining a concept to another person. A feature of this data was that the use of analogies was something that explainers did, for a pedagogical purpose.	"I managed to explain this to one of my friends who's never done any form of computing at all by using the analogy of cereal - If you've got the function cereal bowl and to create your cereal, you have to pass in the term of Corn Flakes and the term to milk and when calling the function a cereal bowl,

			you have to give it the correct parameters because instead of putting in Corn Flakes, if you put in something like toast then it's not gonna end up cereal so there's gonna be a problem in the code.”
	Contextualised Example	Use this code when the explanation resonates with something that the individual has direct, personal experience with. In the included example, a diagram was provided by the lecturer (so the code ‘visual’ code have been used), but in this case, what was important was that the diagram related to the student’s personal experience of working in a hotel.	“It wasn’t until I was in a lecture... and you actually drew up a diagram of a stack of plates going down unto – now I worked in a hotel so for me it made sense.”

<p>‘Non-Pedagogical’ Practices (non-Contemporaneous)</p>			
	<p>Needle in the Haystack</p>	<p>When a student is scavenging through materials online. The use of this code should be for examples that have a feel of a non-targeted approach by students. A feature of this dataset is that there is a moment of discovery, when useful information is found.</p>	<p>“I found a [tutorial] from IBM on the Web written in clear English with diagrams explaining everything and bam, then it was very simple. I don’t know why the other ones made it so complicated.”</p>
	<p>Google</p>	<p>Although Google can be used to find resources, which should be coded as ‘browsing’; this code is for direct reference as to how Google is used for locating appropriate resources.</p>	<p>“I know what keywords to Google in order to help me find the answers that I want quickly, whereas before, I might have to put it up on a forum, and wait for days, whereas now, like the information is always there in the Internet, but I just never knew where to look.”</p>

This section is concerned with people who ask for help in a small local network (~2 people). There are two main categories; initiators (the person who requests help) and explainers (those who provide help).

Type	Code	Description	Example
Social (Private)			
Initiators			
	Asking a Knowledgeable Friend	Asking someone who is relatively close to you (so is still likely to be non-judgemental), but they were asked because they are likely to have the answer.	“We’d be having coffee and I’d go oh James I’m a bit curious why would you ever use this particular construct”
	Putting your hand up	Publically asking an expected expert a question. Use this code instead of ‘Scary Expert Place’ if there is an expectation that the expert is obligated to provide help.	“I’m the dunce in the back of the class that puts up the hand and says, ‘Oh, I didn’t get that,’ and I’m the only one, then, oh, I shouldn’t even be doing the course.”
	Safe Asking	Going to a close friend / family member, because they are non-judgemental. However, this does not necessarily mean that they are the most knowledgeable. (non-expert help).	“I don’t think I ever brought them a program that wasn’t working and I was panicked about and say, ‘This isn’t working. Help me.’ I think I would more go to them, ‘This isn’t working. Help me’ and they – well, just with my mom would sit down and be like, ‘Okay. What is it trying to do? What is this trying to do? What is that

			trying to do?’ And at that point, I would realize there were parts I hadn’t understood.”
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‘Explainers’ qualities originate from the perspective of the initiator; a feature of this dataset is that very few participants describe the help that they provided to others.

Explainers			
	The Nice Guy	Someone who cares enough to help in a non-compelled relationship (not paid or a supervisor). Patient and will spend a lot of time with the person asking for help. Explaining slowly and ‘non-judgemental’	“he’d just explain it patiently you know without judging that I didn’t understand it. Even though I was a third year and I probably should have understood it by then he was very patient.”
	One-Step-Ahead Guy	The provider of a ‘quick-fix’. There is little time investment, but this person helped out because they can emphasise and have been there before, just so happens that this time they have the answer.	“So then when people got stuck on that, I knew what to do and I found it really quite easy now—yeah, kind of that. I wouldn’t say I helped anyone but I showed people what to do.”
	Expected Expert	These are the people who are assumed to have the ‘big answers’. This encompasses lecturers and class supervisors.	<p>“We have the anonymous question and answer pages of things where you can ask lecturers the questions and get the answers back”</p> <p>“my class supervisor was a Ph.D. student, so was just able to go on that and talk to him and say well I don't totally get this, and then just having it explained to sort of make it clear. I'm not so good in lectures when they say something.”</p>

	<p>Compiler says no</p>	<p>This is for when students describe their interactions with the compiler. A feature of this data was that the compiler was regularly personified and the experiences with it were always viewed negatively. Look for struggle and demotivation caused by the compiler.</p> <p>This is perhaps one of the most interesting, unique to computing, codes - A maths sum can be wrong, but it doesn't tell you that it's incorrect and then offers suggestions about how to resolve it.</p>	<p>I remember to the very first day that I ever wrote a program and I sent it to the compiler and the compiler basically – one of those “compiler says no” situation and you just think, “____. I was sure that was right.” And you go, “All right. So what was wrong with it?” and it goes, “Blah, blah, blah, blah, blah.” And you think, “I haven't a clue what you mean” and you have to call someone over. You have to ask someone what it means, and all that self-satisfaction of I can write code and you send it to the compiler and the compiler basically comes back and says, “No, you can't write code.”</p>
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The following category was coded in a number of interview transcripts; however, we are unsure where it fits in with the other categories and its degree of importance (as we don't think we can label this as a *practice*). It has been noted here for possible future use.

<p>Avoidance</p>	<p>Technical Avoiders</p>	<p>People who actively avoid programming related tasks or modules. For those who have experienced it, one type is the 'I'm the documentation guy' that you get in group project work.</p>	<p>"It's really focusing on what I know I could be better at easier. With less effort, I can do a report on systems analysis and whatnot and human-computer interaction. That I get, and I have no problem focusing on that because I can do it, but because programming would require more of an effort from my part, then I choose not to focus on it"</p>
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Table 8: Coding Scheme Table

3.8 Conclusions

Shove's framework defines practices as entities consisting of three interrelated elements: materials, competence, and meaning. *Materials*, broadly, represent physical items, resources and infrastructure, as well as intangibles, such as technologies, and the body. *Competence* includes knowledge, understandings, and skills. For Shove and her colleagues, *meaning* refers to the "social and symbolic significance of participation" in a practice and incorporates individual ideas and aspirations of the participants (Shove, Pantzar and Watson 2012).

Materials determine the form of practice. To give examples from our coding scheme, computer science students rely on books, guidance notes (from the lecturer / supervisor), slides and analogies, to help them visualize and resolve problems whilst programming. The materials discussed in our data were often not created by a student, rather they were obtained from someone else, usually in a formal academic position.

Infrastructure is another important part of materiality, and has a strong influence on the practice that occurs. In our dataset infrastructure (space) was not drawn into the foreground when students spoke about their critical incidents - it was assumed, but not directly spoken about. For example, "we'd be having coffee and I'd go 'oh James, I'm a bit curious why you would ever use this particular construct?'" (coded as a knowledgeable friend), does not explicitly make clear where the two students were having coffee – it is clear that this valued interaction must have happened somewhere, but precisely where is unknown to us.

This was not isolated issue, the students could recall in great detail the event: who they were with, what they were doing, etc. but would rarely describe the space where that interaction took place.

Competence includes academic achievement, interest and skills. In our dataset, students demonstrated a vast array of skills and competencies that they employ when engaging with their studies. We identified individual practices; using the compiler output, code fragments, debug tools and stepping through programs line-by-line. . Many of the practices identified display different levels of competence. Some are at a very basic level and show inexperience - for example randomly changing lines of code in an attempt to resolve a problem. Others, demonstrate a greater level of mastery of the discipline and of its materials, for instance using debugging tools to step through the program. A greater expression of competence is in being the person who others seek out for help.

Students would also often seek help from others in their local environment to help resolve their problems. Students working with each other outside the classroom environment was frequent, in our dataset many (17 out of 29 people) described in their critical incident the role that someone else had in helping them resolve a problem. This also speaks back to what we saw in study one with the second-year students in the Peter Brown Room – help from peers is valued, frequent and offered freely.

In the context of university, meaning, for us (and Computing Education research more broadly) refers to how students identify with the discipline they are studying

and competence in the disciplinary practices they are acquiring. One subset of students stood-out in our dataset in respect of this, ‘avoiders’ were students who actively avoided programming-related tasks or modules in their later years of study. In our data, this frequently followed from a poor experience in the first-year with programming. These students whilst ‘avoiders’ are not drop-outs; they remain in computer science, but have decided that programming is not for them – instead, they prefer to work on topics such as Human Computer Interaction or System Analysis.

In response to research question two *what are the practices that students engage with when they are studying computer science*, the contributions of this study towards this thesis, are:

- The practices of computing are hard to observe, and even harder when all is proceeding smoothly. In using CIT, we bring into focus those points where students come to the limit of their resource. Their practices at those points can be expressed in terms of space, with materials closer to hand or farther away. Use of materials demonstrates their level of competence and can even in some cases express the meaning they have (or are developing for) the discipline, whether they becoming more accomplished or whether they are “avoiding” further engagement with the practice.
- We used CIT to examine student practice. This research method was advantageous because it helped to capture practice *in-situ*, provided a fruitful site for exploring learning and reduced researcher bias.
- We used principles from Grounded Theory to conduct an analysis on this dataset and uncovered a range of practices that students use when they are away from the classroom environment.

- We present a coding scheme table designed for others to use when examining similar datasets. A limitation of qualitative research is that its data origin is from single contexts, and those situations, events, and interactions cannot be replicated by others for generalizations to be made with confidence in a wider context. The use of this coding scheme table is intended to sensitize other researchers to themes that might uncover when conducting similar work.

Chapter 4 - How can we characterize the structure of the different places that students use to support their academic study in our home institution?

4.1 Context

The previous two studies provided a more complete picture of our student's use of space and the practices that they engage with when they are studying computer science; many of these spaces that they identified are beyond our academic control or influence. Whilst it is useful to be aware of this rich ecology, for this final study, we turned our attention to spaces that the Department has specifically provided and attempt to characterize them – we do this, because unlike many of the other spaces that we have identified in this work, we (as a department) provide these spaces in order to attempt to support particular kinds of practice.

To characterise these spaces, we will discuss their physical design, the intention for constructing these spaces, and the student's experience of these spaces.

4.2 Method

For this study we used a technique devised by Padilla et al and described in 'The Unfolding Matrix: A Dialogical Technique for Qualitative Data Acquisition and Analysis' (Padilla and others 1996). In the originating context, Padilla and his colleagues developed and made use of an empty matrix that participants then filled in (in-real-time) during a focus group interview (Figure 20). The subsequent matrix was then used as a qualitative dataset and analyzed.

Barriers	Incidence		Knowledge	Actions	Changes	Problems
	Min	Others				

Figure 21: Padilla’s Empty Matrix – Matrix has been condensed to fit as it can be several feet in length.

Padilla et al devised this as a method to capture students’ “heuristic knowledge”, which they characterise as “locally defined and experientially acquired”. Padilla et al used their matrix to uncover minority students’ behaviours that supported academic success. We used it to examine an equally intangible personal construct: students’ knowledge, experience and expectations of learning spaces.

The advantages of this technique, for us, were that we were able to solicit views from a group, contextualizing individual responses, and that the data collection could be situated – co-located – with the spaces we wanted to study. We also anticipated that there might also be analytic purchase in having the participants contribute to the ordering and categorization of constructs, complementing the researcher-driven grounded theory approach. The metaphorical idea of using a matrix in this way and its ‘unfolding’ during the course of an investigation inspired us to use it as the data collection for this third study.

For our own unfolding matrix, we conducted a set of focus group interviews in three different physical spaces. The spaces were: The Shed [a makerspace], the Common Room and the Peter Brown Room. We utilized opportunistic sampling, by approaching groups of students already working together in one of the spaces and, if they consented, conducting a focus group interview there-and-then. In this way, we could be assured that students were familiar with the space(s) and familiar with working in them. The demographics of the participants of the interview groups were: The Shed – students from stages two and three (male and female), the Common Room – students from stages two and three (male and female), the Peter Brown Room – students from stage two (male only).

For each interview, we planned to project a fresh blank matrix onto a wall using a portable projector; that would allow all participating students to see the grid clearly. However, we found during the course of the study that the grid quickly became too large and unwieldy to navigate. Furthermore, due to the places chosen for this study and the use of opportunistic sampling, we found that rapidly setting up a portable projector was cumbersome. After the second interview, we migrated to presenting a blank matrix on a laptop screen; participants would sit around this and the researcher annotated the grid appropriately under their supervision.

In total, six focus group interviews were undertaken, two in each space, at different times of the day. On average, four to five students volunteered to participate in each group. All of the interviews used the same protocol, were tape-recorded and professionally transcribed.

4.3 Interview Protocol

The primary instrument was a blank matrix, completed over several stages. The first stage was to produce the X axis. To do this, we asked students to list all the places that they commonly used for computational work using the following prompt:

“We are interested in finding out where you like to go to write computer programs. To help us have a base to start from, could you tell us about all the places you go to work? This could be this room [room that the interview is taking place in] of course, but you might also like to think about other places on campus, or off-campus, coffee shops, your home, your bedroom etc. Feel free to shout-out anywhere that comes to mind and I’ll add it to the grid’.”

Once we had a selection of places, we turned to the Y-axis to capture student behaviours. This we solicited in order of difficulty. As we expected that students might wish to debate this ordering, we created a ‘parking lot’ as a space to put entries until consensus on its place in the Y-axis was reached. Students completed this section collaboratively with the following prompt, while the interviewer encouraged the students to narrate aloud their reasoning for their ranking

“Now we would like to find out about what you do when you get stuck with your programming. Do you for help online? Ask a friend? Or maybe go to the lecturer/class supervisor? We will start from top (a little stuck), and work our way down (completely flummoxed). If something comes to mind “out of order” at any stage, just let me know and I’ll put it in the parking lot. We can sort out where it goes later..”

The final stage of the interview moved from group to individual participation. Each student was invited to annotate the grid with a personally meaningful recollection of a time that they were stuck on something related to programming.

Once everyone has had a turn to annotate the grid, the interviewer asks the group to comment on the completed matrix. For example, were there any surprises? or had the examples stimulated further recall?

4.4 What the Matrices revealed

This method resulted in two distinct types of data: the collaboratively constructed artefacts (the matrices) representing the collective view of the participants, and the transcripts of the discussion surrounding the elicitation. The collaboratively constructed artefacts help support our findings from our previous two studies and we draw upon these artefacts first. The discussions gave insight into the different qualities of interaction that the different spaces afford, and we draw on these in the second part of this chapter.

4.5 The Constructed Matrices

For our initial analysis of this data, we extracted the Y-axis and X-axis of each of our matrices and placed each into their own table (a table consisting of all the cells from the X-Axis and a second table consisting of all the cells from the Y-Axis). For the X-Axis of each matrix, we loosely grouped each space under the following categories: Home space, School provided space, University provided space, Unsuitable space (where work was happening in a situation /space not meant for that activity), Other, Ambiguous.

4.6 X-Axis Table

Interview Transcript	Home space	School provided space	University provided space			"Unsuitable" space	Other	Ambiguous
Common Room 1	At desk at home in front of computer	Common Room (Sitting Area)	Study Hub (Keynes)	Silent Area of Library	Library Computer Room	During Lectures	Train Journeys (Long)	
Common Room 2	Home Desk	Common Room	Senate Study Hub	Library Social Study	Darwin Computer Room	Origins Bar		
	Off-Campus, home, at desk	Peter Brown Room						
	Home Dining Room Table							
	Home Bed							
Peter Brown Room	Bed	Peter Brown Room	Rutherford Study Hub	Library	Library Computer Rooms	Lectures	Car	
	Friends house	Common room	Senate	Level 4 of the Library		Seminar / Terminal classes	Doctor Surgery	
	Home (London, etc.)		Marlowe (upstairs table)	Study Room Library			Cafes	
	Living room		(in the first year) Bottom of Colyer Fergusson				Bathroom	
	Kitchen		(in the second year) Top of Colyer Fergusson				Plane	
	Girlfriend's house						Train	
							London Underground	
							Bus	

Interview Transcript	Home space	School provided space	University provided space			"Unsuitable" space	Other	Ambiguous
							Sports Center (changing rooms)	
Peter Brown Room 2	Off-Campus, home, at desk	Peter Brown Room		Library (silent area)		Lectures		
	Front Room							
	In bed at home							
	First year - on campus accommodation							
Shed 1	Bed before getting up	The Shed		Program at Library (not often)			Train	Lounge with Friends
	Bed before going to bed	Computer Room (The Peter Brown Room)						Computer Lab
	Going to friends house	Common Room						
		Homework Club (in The Peter Brown Room)						
Shed 2	Computer Room at Home	The Shed						Desk
	Bed	The Peter Brown Room						Lecture Theatres
	Kitchen Table	Common Room						
	The Garden							
	Around Parents House							

Table 9: Constructed Matrices, X-Axis Table

4.7 X-Axis Table Discussion

The X-Axis of the Unfolding Matrices, Table 9, shows a similar diversity of space as we saw in the first research study.

The participants in this research study (comprised of second- and third-year students) use far fewer bars and cafés to work in, with only ‘Origins Bar’ (the bar that is the closest to the School of Computing) being mentioned. This strengthens our original conclusion, of study one (diary study), that the bars and cafés were used by the first-year students because they were visible to them (as they lived in close proximity to them) and that they served as ‘neutral territory’ (the students preferred to meet at these locations, rather than going to each other’s study bedroom).

We also uncovered in study one, that the first-year students regularly utilised unoccupied seminar and lecture rooms to work in; however, the participants here do not describe a similar use of these rooms – instead, they more regularly use non-timetabled spaces that are explicitly provided by the university/school for academic study: the Common Room and the Peter Brown Room. This would add support to our belief that during their course of study, students gradually identify spaces that are ‘private’ to the department and come to understand the purpose of those rooms; as this happens, students begin to adapt their use of space, shifting from exploiting rooms that they know about from timetabled classes, to using spaces dedicated for specific academic purposes.

A difference in space use also arises within the different interviews. The interviews that took place in The Shed, are the only ones that identify ‘The Shed’ as a place to

work; those that work in the Shed still identify the Common Room and the Peter Brown Room as places that they work, but this relationship is not reciprocal. There are a few possible reasons for this. First, The Shed was a relatively new space compared with the common room and Peter Brown room – the wider student community may have yet to identify it as a potential space to work in. Second, the room has less desk space for laptops and few computers, and therefore can support fewer students than the other two spaces, as such it may be viewed as an inappropriate space to casually work in. Third, the group of students who use this space (mostly female) may have ‘laid claim’ to this space and so other students, don’t venture there unless welcomed / encouraged to.

We also observe in this dataset that students use the time whilst they are transiting for academic study. Whilst we did not observe this in study one, other researchers in related literature (Kim Wu and Lanclos 2011; Gourlay 2010) have done so. The length of travel and its network connectivity is an important part of working whilst transiting – students only participated in academic study during longer transit times (greater than campus to town) and if Internet connectivity was available.

Finally, we see the same physical space supporting different expressions of place. The Peter Brown Room is normally available for use by all School of Computing students; however, three times a week ‘Homework Club’ takes place here. The Homework Club is a place that first-year students can voluntarily go to for help with material in all their academic modules. It is staffed by second- and third-year students that successfully completed the first-year. The experiences within these places, even though they are physically co-located in the same space, is quite

different; different enough for the students to talk about them as two separate things when asked the question “where do you go to work”?

4.8 Y-Axis Table

Common Room 2	PBR	PBR2	Shed 1	Shed 2
Read code over again - Couple print statements	Debug (syntax)	Pen and Paper	IDE Prediction	Check for Spelling Errors / Missing Semi-Colons
Debug Step through the area (rare)	Debug (IDE tools, in some cases)	Try googling	Language or Library Documentation	Compiler Output
Let Google do the sorting - Stackoverflow	Google	Stepping Through the Program -- Not debug tools, read.	Google	Review Language Documentation
Google - Language Level - Official Docs	Stack Overflow	Debug, certain errors (null pointer, maths) or when almost there (locating error)	Friends in Room	Google
Google - YouTube - topic	w3schools (web stuff)	Take a break	Lecture Slides	Stack Overflow
Ask friends on sport team (graduates)	Re-read Question to see if doing it right	Ask a Friend (Talk through the problem)	Google again (specific application)	Whiteboard / Notepad -- write it in English / state diagrams
Ask peers, everyone knows we are all working on it - Point in direction.	Ask a Friend on the course (close buddy) - Facebook	Ask a Friend (between classes)	Approach someone (locally) in same year / doing same thing	Asking Around
Facebook Message - Seminar Mates	Lecture slides, Books, Anonymous Questions (Formal Stuff)	Check against and Work in Lectures	Go Away (sleep / coffee)	PhD students - Seminar Leaders
Meet as a group and try together	Take a Break (play some football, go for a drive)	Check Notes	Rubber Duck	IRC – though Sarcastic / not helpful

Common Room 2	PBR	PBR2	Shed 1	Shed 2
Go and Do something else (forces me to re-read further up)	Homework Club	Anonymous Questions and Answers	Seek out a friend (knowledgeable / Doing same thing)	Facebook
Lecturer - One of us go - Spec of the assignment	Speak to the Lecturer	Speak to Lecturer	Seek out a postgrad (supervisor of that module / teaches something similar)	Friends
	Give up, just submit	Listen in to Lecturer	Homework Club	People who have done similar Stuff
		Email Lecturer	Lecturer	Lecturer
		Throw Away and Restart		Stop, Delete, Redo
				Take a break

Table 10: Constructed Matrices, Y-Axis Table

4.9 Y-Axis Table Discussion

The Y-Axis of the Unfolding Matrices, Table 10, revealed that what students do when they get stuck is relatively consistent across the cohort. Many of the practices that they identify here also share a consistency with the CIT Study (Study two).

What we gain from this dataset, which we did not from the CIT study, is an order to these practices. When students encounter a problem, whilst programming, they first take an individual approach to attempt to solve the problem: debugging, stepping through code, documentation, etc. Failing this, they shift to using the Internet to find external resources for help (Stack Overflow, etc.). They then resort to asking their peers and this is generally a friend or someone who they can trust. The next stage is more diverse, but includes: looking at notes, anonymous questions and answers, homework club (a support group that is supervised by students from subsequent year groups) and PhD students. Finally, the students approach the lecturer for help or give up or seek help from someone on the course.

It is surprising that the lecturer is considered a last resort when everything else has 'failed'. A set of observation sessions that was conducted during this research (Knox and Fincher 2013) identified that this was not an isolated occurrence, but instead was common behaviour; the students do view the lecturers as 'experts' who have the 'big answers', but despite this, students will first approach friends and knowledgeable peers for support; these are the 'Knowledgeable Friends', 'Nice Guys', 'One Step Ahead Guy', and 'Providers' as categorised in the CIT study.

4.10 Semiotic Social Spaces

As an academic institution, we construct spaces that we have designed to be used in particular ways. Some are provided and managed by the estates department for general use by the university, others are created and provided at a department level. It is these departmental spaces that we are interested in because they are ‘insider’ spaces - not obvious to students until they arrive at the university and locations of practice. They include both physical and virtual spaces. The spaces are: The Common Room, The Peter Brown Room, The Shed, The Kent I.T Clinic, KentIRC and the School of Computing Facebook groups. The dataset used for this was the unfolding matrix transcripts and an additional focus-group interview that took place in the KITC².

We draw on a framework developed by Gee (Barton and Tusting 2005, pp.214–232) which he developed in response to existing theories, such as Communities of Practice (Wenger 2000). He contested that whilst they theories were useful for attempting to understand interaction in certain kinds of communities, they were problematic when applied in an education context. A Communities of Practice approach requires labelling a group of people, i.e. who is part of the community and who is not, (Barton and Tusting 2005, p.216) and it can be difficult to define “what actually constitutes a community of practice in a study context as there may be many such communities on a single programme of study” (Walker 2006). Gee proposed that it may be more fruitful identifying spaces in which people interact and that what actually links learners is their mutual participation in ‘Semiotic Social Spaces’.

² This interview did not use the Unfolding Matrix (UM) protocol and was held prior to the UM interviews. It was concerned with the work and activities that take place in the KITC.

Gee's construct of 'Affinity Spaces', share many similarities with the spaces that we have uncovered in this work:

- They are places where people affiliate with others based primarily on a shared common endeavour;
- Affordances within the space is not fixed, but are transformed by interaction;
- Individual and distributed knowledge are valued;
- Many forms and routes to participation are available;
- Leadership is porous and leaders are resources. (Barton and Tusting 2005, p.228) .

Gee provides the following definition of a semiotic social space:

First, all semiotic social spaces are comprised of a *Generator* which provides a source for a set of signs. In a science classroom, the generator could be a textbook, the teacher, the lab materials, etc. (Barton and Tusting 2005, p.221). The signs that a generator produces can be viewed in two different ways, an *Internal Grammar*³ and an *External Grammar*. The internal grammar describes the design, patterns and configuration of a generator; in a science classroom, this might be the physical layout of content in a textbook, the availability and positioning of lab materials, etc. The external grammar comprises people's thoughts, values, actions and social interactions in regards to the generator; in a science classroom, this would be the interaction between the students and the teacher, how the textbook is used, the students' opinions and understanding of science, etc. Finally, semiotic social spaces have one or *portals*, which are simply how a person accesses the generator. This

³ Grammar is defined as "phenomena that are emergent" (Barton and Tusting 2005, p.219)

could be physical (e.g. through a door into the science classroom), metaphysical (the textbook is accessed via the teacher reading the content from it) or even virtual (interactive media that accompanies the textbook is available online).

Gee's definition serves as a useful framework for presenting a rich description of the spaces that we visit in this study. For each of these spaces identified we provide: a descriptor of the generator and portals, its internal grammar, which will be presented as an in-depth overview of the space's physical design (including floorplans), and for the external grammar, the students' experience of that space obtained from the interview transcripts. Using the external grammar of each space, we will also draw parallels with related literature.

The Common Room

Generator(s):

A social space exclusively for use by students from the School of Computing; use of the room is monitored and enforced

Portals:

Physical access via two doors – one leads onto a main corridor (opened) and a second (unlocked, but closed) to a lecture theatre

Internal Grammar (Figure 22):

The room is unlocked each day at 8am and people are asked to leave by 7pm (the room used to close earlier, but students requested longer access).

On the right-hand side of the room is a set of circular tables with four chairs around each one. Groups of students regularly sit here with their laptops and work with each

other. There are power sockets embedded in the floor accessible from a small hatch. In the corner of the room is a set of bookshelves containing hardcopies of all MSc and PhD theses from the department.

On the left-hand side is a desk that runs the length of the room; several chairs are placed along it and various free books and information leaflets are placed on top of it; some students work here individually with their laptops. Power sockets line the wall.

At the far end of the room is a horseshoe layout of 'lounge' chairs with low-height tables in the middle. Students hang out in this area chatting with each other, putting their feet up on the tables and working on their laptops. At the request of students, a whiteboard has been installed on the wall in the last year; students use this for sharing jokes and explaining academic content.

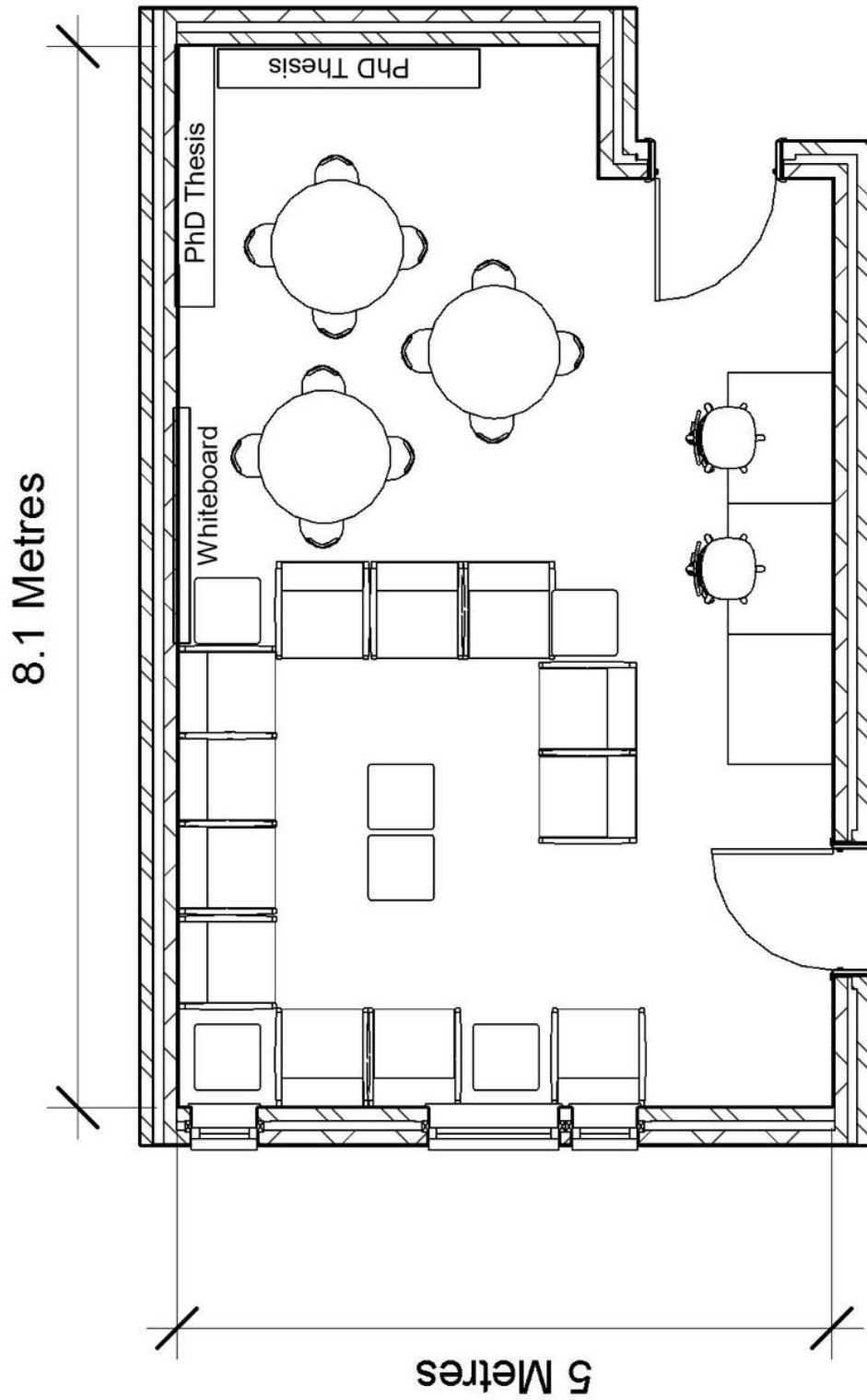


Figure 22: Floorplan of the Common Room



Figure 23: Photograph of the Common Room

External Grammar:

During the week that the interviews were conducted for the Unfolding Matrix, groups of students from the second year of study were marking submissions for a Software Engineering assessment. Each group was given at random another group's submission and were asked to test and evaluate it.

One of the focus groups that volunteered to participate in the study was marking another group's submission during the interview. At one point, a student (who was not participating in the interview and was from a separate group) began talking to one of the participants:

Carl: *"Which group are you?"*

Alvin: *"Thirty-Six"*

Carl: *"Do you want to check my thing out?"*

Alvin: *"No I don't want to check it out."*

Carl: *"Go on, check my thing out."*

Alvin: *"We've got to have access to be able to."*

Carl: *"It might be possible, go-on check it, it's really cool."*

This cross-talk has a 'competitive' feel about it; the student is clearly confident with intruding into the focus group and is persistent in encouraging the interview participant to look at their work. This was not the only 'intrusion':

Sam: *"Which group are you marking?"*

Darren: *"Two."*

Sam: *"Who's in it?"*

Darren: *"I don't know..."*

Darren: *"I've discovered a really major problem with this group, not this group's approach, but with the way it's setup on Raptor [Raptor is a shared access Unix server.] They have used an XML file for their database, but it's read-only on Raptor. Obviously I could just 'chmod' it on my own local copy, but I don't think the average person is going to work out that they need to do that on a read-only file. Which is why I wanted to use a database, because I thought that would be -"*

Sam: *"The assessment brief didn't say that I had to work on Raptor, it just had to work on the university PC wasn't it?"*

Darren: *"Yes, but if you copy the file from Raptor it's going to have the same file permissions."*

Sam: *"I see."*

Darren: *"So its going to say 'no'."*

Whilst 'Sam' did not solicit help with a problem, in this example Darren takes the time to explain an issue that he has found with another group's submission and how he would resolve/avoid the problem.

The Peter Brown Room

Generator(s):

A suite of computers that are available exclusively for use by computer science students.

Portals:

Physical access via a single door that leads onto a main corridor.

Internal Grammar (Figure 24):

The room is open daily between 8am-7pm and is available exclusively for use by computer science students. It is rectangular shaped and there are tables along each side with desktop computers and power sockets. There is a centre island running most of the length, also with workstations. A small whiteboard is in the right-hand corner by the window. A larger whiteboard is on the right by the door.

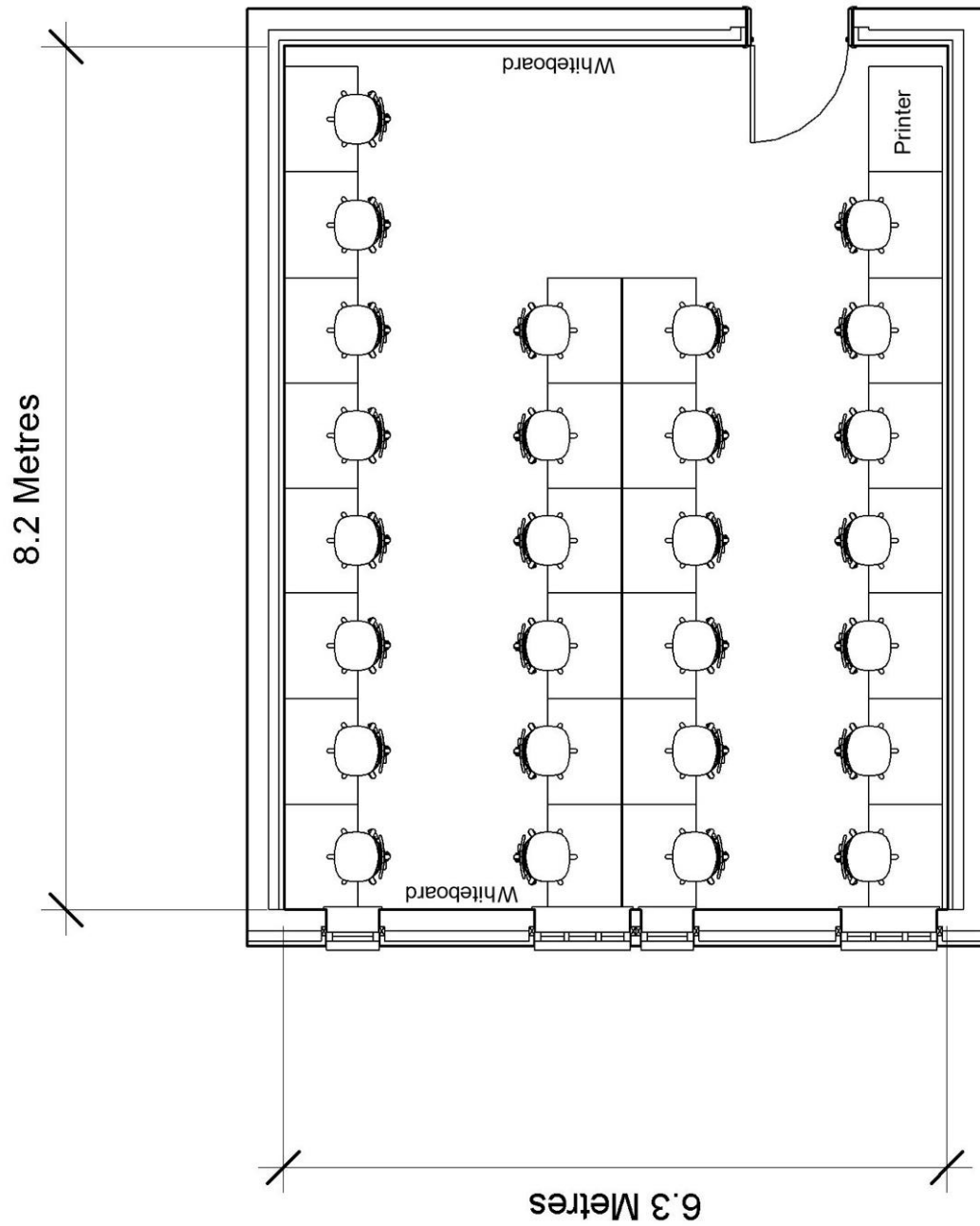


Figure 24: Floorplan of the Peter Brown Room



Figure 25: Photograph of the Peter Brown Room

External Grammar:

In ‘Study One – Diary Study’, the students we interviewed described the kind of help that they had found in the Peter Brown Room; often the help provided and received was casual, informal and unsolicited. In the Unfolding Matrix intervention, we observed a different group of second-year students.

Alan: *“In [the computer room] we normally just Google. Like, when people discuss problems and stuff they always go on Google.”*

Neil: *“Proving people wrong.”*

Alan: *“Showing people where -”*

Neil: *“I always phone a friend as well. We normally ask friends in the common room or the computer room because that’s where we’re most likely to see them..”*

Here, Neil supports our earlier observation that second-year students come to this room because they expect to find others in this place.

Researcher: *“Is this generally a close friend or someone on the course?”*

Neil: *“I think it’s friend first and then if no one can help -”*

Alan: *“Then you get desperate.”*

Neil: *“Yes, ask some stranger.”*

Alan: *“Another thing, when people are working in here, and if they’ve done it and they can see you’re stuck, they will just instantly help you or they will just give you some help. I would do the same if I was in here and I’d saw someone stuck for about half an hour, I’d thought -”*

Neil: *“No one’s ever done that to me. Has someone done it to you?”*

Alan: *“Well like one of you guys -”*

Neil: *“Well they laugh at you first and then they help you...”*

In an ethnographic study of computer science learning environments, Barker et al (Barker, Garvin-Doxas and Jackson 2006) found that

“Informal hierarchy is created through the acquisition and display of status by participants in a social situation and is relevant to the values shared by members. Individuals learn the values of groups in subtle ways through interaction and present themselves as members through the expression of shared values; they make a bid to be treated as having higher status when they talk in ways that suggest they excel at the kind of skills required for functioning in that social context. In computer science classrooms, status is informally accorded to those who display technical skill or provide valued information” (Barker, Garvin-Doxas and Jackson 2006, p.45)

The description provided by the students about the disciplinary working in the Common Room and the Peter Brown Room resonates strongly with the findings of Barker et al. Barker et al. go on to suggest that “these communication patterns lead to a defensive climate, characterized by competitiveness rather than cooperation, judgements about others, superiority, and neutrality rather than empathy” (Barker,

Garvin-Doxas and Jackson 2006, p.44). That these kinds of interaction are typical of, and expected in, these places was also corroborated in our interviews:

Philip: *“I prefer working in the library, because you can - sometimes I feel intimidated working in here.”*

The Shed - A Makerspace

Generator(s):

A space equipped with a variety of machines to allow students and staff of the school of computing to make things.

Portals:

Physical access via two doors – one main at the front of the building and one at the rear. Has a Facebook that provides information to the public and recent projects.

Internal Grammar (Figure 26):

The Shed had been open a little under a year at the time of this research; it is a purpose-built building, located next to the department within a courtyard and is equipped with a wide variety of machines and development equipment. It is formally open from 9am-5pm on weekdays (although people do come in much earlier) and was supervised by two part-time technicians, who were PhD students in the School. Students and staff of the School can use The Shed to support their learning for taught modules, but they can use the facilities for their own personal interests and hobbies as well. They get priority on the machines and free access to materials; however, people from other departments are also allowed access.

As you enter the building, on your left and right-hand sides are two plant rooms; these contain a large supply of electronic components and materials. Some long-term student projects are stored in these rooms and one of the student societies, a society

dedicated to Making, also has its own cabinet located in there. Access to these two rooms is restricted.

Passing these, the building opens up - it is rectangular and a whiteboard material clads all of the walls - mechanical designs and computer programs are sketched across it in all areas. The roof skylights, windows on all sides and LED lighting, in combination with this whiteboard material, give the room a very light and airy feel. Because of the layout of the tables (which are 1 metre deep), the room has a natural divide to it. The front is dedicated to design; this is where group meetings, prototyping and machines, such as the vinyl cutter are located; eating and drinking is also allowed in this area. Three computer workstations are located in the left-hand corner of this area; the technicians commonly sit here. In the right-hand corner of this area is a wall-mounted TV, cart with prototyping materials and several vinyl covered cubes for seating; a couple of students regularly use this area for relaxing.

The rear half of the room is the 'workshop area'; this is where the larger machines are located, such as the laser cutter, 3D printers, soldering, pillar drill and several CNC milling machines; eating and drinking is not allowed in this area and a 'workshop' dress code is enforced.



Figure 26: Floorplan of The Shed



Figure 27: Photograph of The Shed

External Grammar

In a focus group interview, one of the students (who regularly works in The Shed) described why they work there, rather than in one of the other spaces that are available for use:

Jennifer: *“If I’m actively trying to work, then I’d go to The Shed, otherwise the Common Room because there’s comfier seats and it doesn’t matter if you don’t end up getting work done because you’re talking to other people...”*

Researcher: *“Why do you find The Shed a better place to work if you want to just focus on something?”*

Jennifer: *“It’s quieter. There’s [the technicians], for help, when things go wrong. [A PhD student] is in here half of the time now as well”.*

In this, Jennifer describes her motivations for going to two different spaces. The Common Room because “there’s comfier seats” and The Shed because it is quieter and ‘expert’ help. Another student, Jane, reported a similar experience:

Jane: *“The Common Room’s good up until about 10 o’clock and then it turns into a Common Room obviously (laughter).”*

Mike: *“Students wake up.”*

Jane: *“It was literally dead on 10 o’clock and people would start coming in and then it was really hard to work whereas in here it’s quiet most the day. Even when people are working they’re working quite quietly, they’re not shouting about and listening to loud music.”*

During the interview, the students spoke about the kind of help that they had received in The Shed:

Anna: *“I was doing algorithms last term, we had to do binary search trees. I had to remove one half of the tree and lots of help was given, drawing lots of search trees on the whiteboards in here. Actually trying to understand what was going on.”*

Researcher: *“So why do you work in the Shed?”*

Carl: *“Because [the technicians] are always here.”*

Anna: *“Always someone who will help in here and there’s lots of whiteboard space to explain things through.”*

Researcher: *“And is that even if they are not the supervisor of a module?”*

Anna: *“Yes.”*

Here, Anna and Carl (like Jennifer) recognize the help that they receive from the technicians and go to The Shed because they know that in this place they can always find help. In addition, the physical features, the materiality of the space, such as the whiteboard walls, are important in affording this help. In contrast, with the Peter Brown Room and the Common Room, the help that the students expect to find here is different – in the Shed, the technicians are employed by School of Computing to work in that space and to support the activities in that environment, furthermore their status and knowledge has been reified by their completion of the computer science

degree programme and their employment by the school; as such, it is a space where students can expect to find an 'expert' for help due to their defined working hours.

In a recent conference paper on the community and help found in Hackerspaces, the researchers found that the:

“Culture of Hackerspaces was one of collaboration, interpersonal support and co-operation - Hackerspaces, by their very nature, required the members and managers to actively cultivate these elements in their space, in order to successfully maintain and grow their community” (Toombs, Bardzell and Bardzell 2015, p.1).

The description provided by the students about The Shed characterizes it as a place of interpersonal support and co-operation, rather than competitiveness.

The KITC

Generator(s):

A dedicated space provided by the School of Computing for a consultancy company that is staffed by students.

Portals:

Physical access via a single door that leads onto a corridor. Has a webpage that provides information to the public and the staff communicate with each other using software tools.

Internal Grammar (Figure 28):

The Kent IT Clinic (KITC) is a consultancy company that operates within the School of Computing at the University of Kent. It was founded in 2004 and offers for a fee, IT services to internal and external organizations. Students from computer science or business degree programmes staff the KITC and work on the projects that the clinic

takes on. The students, known in the KITC as consultants, are unpaid but receive academic credit for their work. The credit contributes towards a student's final degree classification and working in the KITC is instead of a final year 'dissertation' - normally a group-based technical project or an individual research project.

The KITC has two contrasting aspects, an academic and a business focus, and this duality is reflected in its structure. Supervisors, who are university academics, are concerned with the academic side of the KITC; they review and support students' learning, ensuring they are demonstrating a grasp of both soft skills and technical skills. In contrast, the coordinators, employed by the university, are solely concerned with the business aspect of the KITC. They ensure that deadlines are being met and that work is of an acceptable standard. They also arrange and organize new contracts with clients. As such, projects are always aimed to be within the abilities and capacity of the consultants. The coordinators are also capable IT professionals and serve as a final 'backup' in case projects encounter problems.

The KITC, is physically located at two of the university's campuses, Canterbury and Medway. Each location is home to several teams of consultants at any one time, who work on the projects that the KITC takes on. The projects are distributed equally between these teams, depending upon current workload and expertise. On occasions, more than one team works on the same project; however, projects are never duplicated. Although located at different campuses, all of the teams meet weekly through video conferencing and share knowledge via a business knowledge management system.

To work in the KITC, students must complete several prerequisites. First, students are required to have taken the *IT Consultancy Methods* module. The module's syllabus utilizes case studies to develop an understanding of business techniques, risk assessment, evaluation and an appreciation of customer relations, legal and ethical issues and presentation. The *IT Consultancy Methods* module is not situated within the KITC; it is an academic theory module and is designed not only to support students who wish to work in the KITC, but also for any student interested in IT consultancy. Second, students must attend and be successful at an interview. The director conducts interviews annually and, with the advice of the current consultants, selects a limited number of new consultants. The total number of places available in the KITC each year varies depending on the predicted business demands and the capacity of the supervisors and coordinators.

Because a new team of consultants is 'hired' each year, turnover in the KITC is high. This means that at the beginning of the year, time is required for the new consultants to 'learn-the-ropes' and to become confident and competent in the clinic's systems and processes. This is one of the main contrasts between the KITC and a real IT consultancy company.

Work in the KITC is timetabled; however, the purpose of timetabling is only to ensure that time away from other modules is protected. It is up to the consultants to decide how this time is used. Frequently, as all of the consultants have the same timetabled hours, they use this time to meet, discuss projects and operate the 'laptop repair service' - a service offered at the university where the consultants will repair students and staff laptops for a fee. All of the consultants work additional hours in

the KITC. This time is used by the consultants to work on KITC projects, but also means that individuals in teams work on their own component for each project. The importance of this, unlike other spaces within the School of Computing, is that the consultants are given the ability physically to access and open the KITC facilities whenever they desire.

The KITC has been developed to mimic a 'real' IT consultancy firm; as such, the clinic charges a fee for the work done for clients, thus, the clients have the same expectations as they would for any other supplier. This means that unlike assignments from other modules, the work done in the KITC has a personal and commercial purpose.

On the Medway campus the KITC occupies a rectangular room, on the second floor of a University of Kent building. Along the corridor are similar offices and seminar rooms used by the School of Computing. The door to the room is on the right-hand side of its longest length, as you walk through the door, to your left is the rear of a storage cabinet and you are forced to walk around the room's breath. Opposite the entrance is a small, enclosed office that belongs to a coordinator of the KITC; it is currently unoccupied as the coordinator is visiting a KITC room at the other campus. The office is permanently unlocked so that the student consultants can use the space as a private meeting room. On your left is a notice board, on it is: a sign-in sheet, folders containing various forms and a 'team of the month' certificate that one of the consultants has developed and printed.

In the centre of the room is a large meeting desk and around the edge of the room are workstations. Although not explicitly allocated, each member of the KITC has their own 'spot'. On the walls are whiteboards (covered in: notes, deadlines, planned events and allocated project work), a photo board of all the members of the KITC, and a large flat screen used for video conferencing with the KITC located at the other campus (currently not working).

The room also houses the 'laptop repair station'. There are storage cupboards to safely lock away laptops when not in use and there is a workstation equipped with a set of technicians' tools.

On the Canterbury campus the KITC occupies two adjoining rooms (Figure 29). The KITC at Canterbury, although physically is located in the same building as the rest of the School of Computing, is a short distance away from the other rooms that are owned by the department. As you enter, to your left is fixed bench space for repairing computers, there is also a shuttered hatch for customers to turn up to pick-up and drop-off their laptops. A second door, leads to the rear room (the terminal room) and in here are a number of PC's/hot desks.

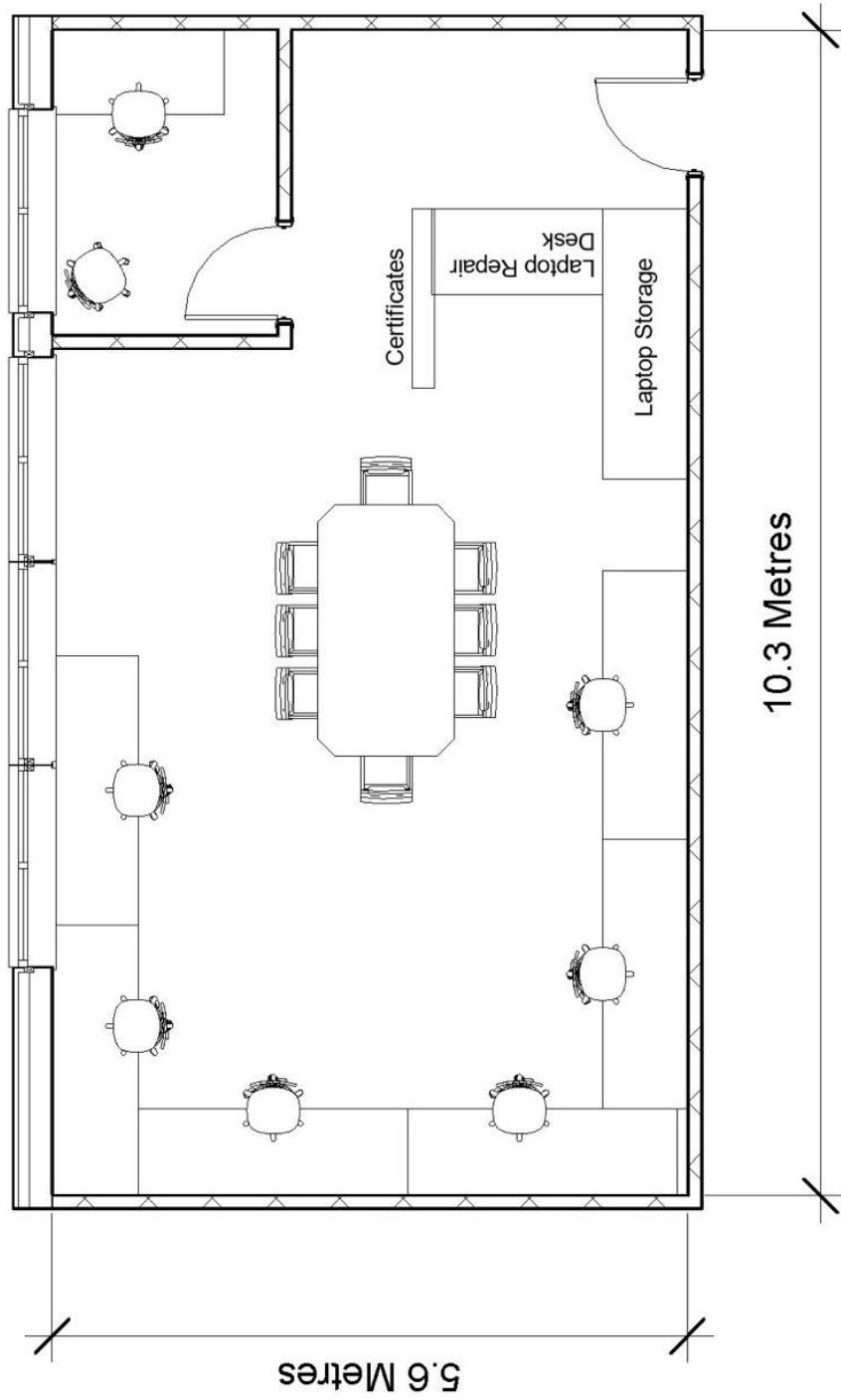


Figure 28: Floorplan of the KITC at Medway

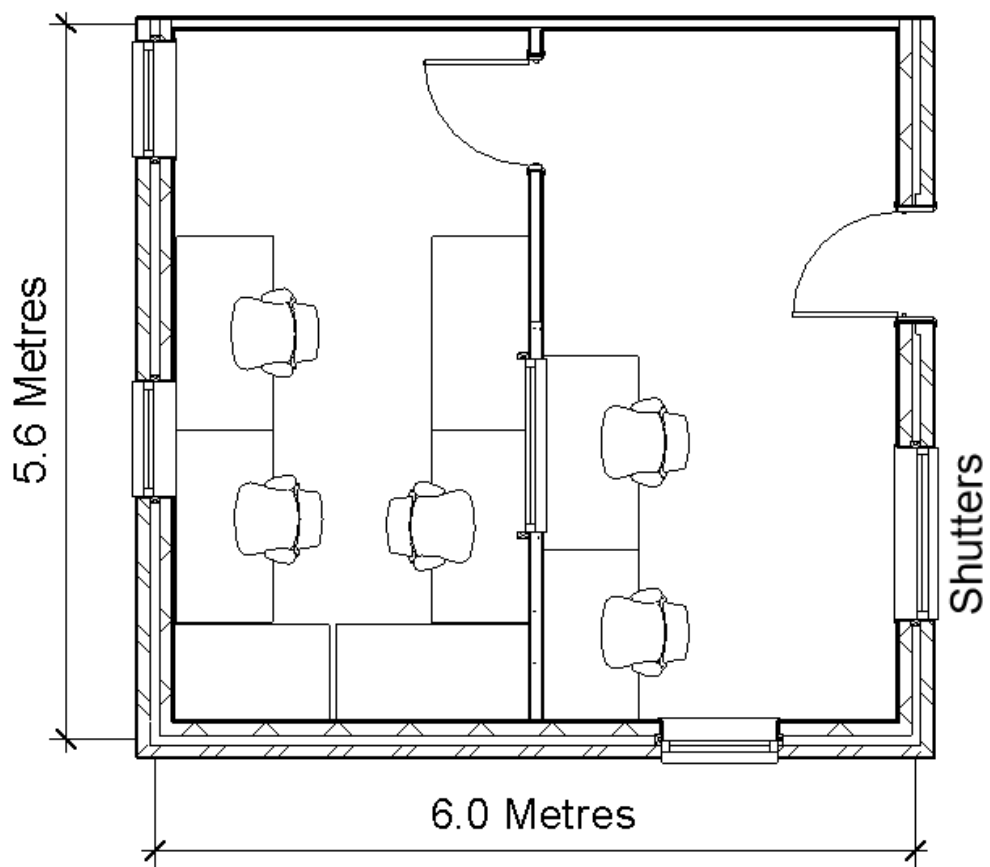


Figure 29: Floorplan of the KITC at Canterbury

External Grammar:

The students have a particular relationship with KITC work, and to the KITC room:

Sidd: "... you learn so much, and you're not working on a "Mickey Mouse" project, you're working on something that actually has to go out and someone is going to use. You need to make it good otherwise you're going to get a lot of complaints ... everyone knows that this is a serious place to be."

The students attribute expected differences to the demands of this sort of work, which is "real" work that will be deployed to external clients; but unexpectedly extend these to the attitudes of the students who work in their team, and alongside them in other teams.

Sidd: "... you can have as long [as you need] as [long as the] work gets done."

Anita: "So I've worked with a couple of people on coursework deadlines and things like that, and they're completely different to how they act in here ... I've actually had this piece of work, there were three of us, one person didn't do anything ... That wouldn't happen in here, I've never seen that in here where one person hasn't done anything, it just wouldn't happen."

They contrast being in the KITC with the different demands of academic work:

Anita: "... when you do coursework you've learnt throughout your lectures and then it's usually a coursework related to those lectures. Whereas in here you're, kind of, put into a situation and you've got to learn the systems ... Also, when you get given coursework, I guarantee you about 60% of the students start their coursework a week before. No doubt about it."

Sidd: "[coursework] didn't matter. In the sense that, yes you would get graded on it, but if you were to do it at the last minute no one's going to know."

They strongly differentiate their scaffolded academic learning, with the learning that the client-driven work in the KITC necessitates. They recognize the drivers for this, and also recognize that their responses draw on different strategies.

Anita: *“PHP is an example; I haven’t had any experience with PHP. So I had to learn it on the job, literally ... So it wasn’t simple, at all, because I find PHP quite difficult, if I’m honest. But something that I do look to is coaching. ... one of my team members, he’s amazing at PHP, a really technical guy. All he does is sit there in front of the computer and code all his life. So I just literally sat there and watched him ... looking at his work. It helps me to understand what he’s doing, and he would explain it to me as he was going along. Coaching is used quite widely in the KITC.”*

Sidd: *“Everyone helps each other out where ever they can, which is really good. It’s not something you see in other modules, mainly because if you do try and do that you’re going to get done for plagiarism ... it’s more real life, so you can be assisted to certain goals rather than not being able to receive help.”*

They expand this notion of being assisted, being coached to achieve goals, to other non-technical skills

Anita: *“Another thing is ... you often get feedback on the way you are as a person. So one feedback they gave me that I’d proved that I’d done a lot of management skills, but the next thing I need to look for is more leadership skills, which is why I took on this role. You don’t get that in University; no one really says “You need to build your confidence.” There’s no one to give you that sort of support. It’s more, if you’ve done your coursework, “You’ve done well”, “You got a zero” or “You got 70” - and then that’s it on how to improve your coursework. There’s no feedback on “Yes, you managed the group really well. What kind of role did you take?” It’s just things like that you don’t really get through coursework.”*

For them the door to the KITC is a genuine threshold; as they pass over that different opportunities and different behaviours are enabled, even though they do not actually leave the educational environment at all.

Virtual Spaces - IRC

Generator(s):

Online media space that provides students the ability to communicate. IRC supports continuous conversation.

Portals:

Via a client applications or run in the web-browser. A webpage is provided for the IRC group

Internal Grammar:

KentIRC is the IRC network provided by the Kent Computing Society. IRC stands for Internet Relay Chat, a way of chatting in real time with individuals and groups ("channels") of people. A student within the department set up the first IRC server and the service sometime during mid 1999. The service then expanded to other servers over the years and became used by a far wider audience than the original CS students that it started out with. Unlike the others spaces that have been described, KentIRC has a webpage that explains the purpose and history of the service. Members of KentIRC occasionally attempt to 'recruit' / encourage new members by advertising the service to others on the display screens that are located around the school.

External Grammar

During one of the Unfolding Matrix interviews, one of the participants spoke about their use of IRC:

Tobrin: *"IRC?"*

Simon: *"People on IRC, maybe. They're not very useful usually."*

Interviewer: *Why aren't they useful?"*

Simon: *"Usually they either don't know, don't know what you're talking about or you just get a sarcastic answer."*

Tobrin: *"That does sound like IRC."*

Simon: *"Yes. They're not the friendliest bunch of people."*

Interviewer: *“Why do you participate on IRC if they’re just going to be-?”*

Simon: *“I don’t, mostly. I’m on IRC so I can contact people directly. I mostly ignore the main channels these days.”*

Tobrin’s and Simon’s experience of IRC is similar to the ‘defensive climate’ observed in the Common Room and Peter Brown Room; as such, Simon’s experience has lead him to mostly ignore the channels where this interaction takes place. Simon also demonstrates considerable knowledge of this virtual space - he knows of the people who use IRC, when they are active, and that this is a way of contacting them; as such, he uses IRC as a way of getting in direct contact with specific people to ask questions. Simon’s use of IRC resembles the ‘visitor’ mode of White’s Visitor and Resident theory (White and Cornu 2011), whilst some interact on IRC as members of a community and invest time in developing it as a place (residents), Simon’s deliberate use of IRC is much more just a tool to directly contact people to whom he wishes to speak.

Virtual Spaces - Facebook

Generator:

Online media spaces that provide students the ability to communicate.

Facebook uses a 'post' format for communication.

Portals:

Via a client applications or run in the web-browser.

Internal Grammar:

Facebook has a complicated ecology due to the existence of multiple

Facebook groups. The groups are: [Tom's Group], Computer Science 2011, 2010, 2009 and School of Computing.

Tom's Group was created by Tom (an established lecturer in the School of Computing) and comprises approximately 240 active members. Access to the group is closed with access approved by Tom (or if someone else vouches for you). Many of the members are current undergraduate and postgraduate research students from the School of Computing, but there are also some graduates. Following Tom's interests, the group frequently discusses old computers, new technology and the sharing of general digital news. This group is separate from the other School of Computing Groups.

The Computer Science 2011, 2010 and 2009 are ongoing groups. The original purpose of these groups was to provide a place where potential

applicants can ask questions about the undergraduate courses and the admissions process.

Student helpers who assist on school open-days are made members of this group, so that they can respond to applicants' questions. Applicants are invited to join the group when they attend an interview (a normal part of the admissions process). At the start of the academic year, each group is renamed to reflect that year of entry and successful applicants (now undergraduates) continue to have access; unsuccessful applicants are removed. Administrator access and control of the group is handed over to the students at this time. On average, there are 167 members in each group. The 'School of Computing' group was created by the Course Representatives. Course Representatives are students who are elected annually by the other undergraduate students to represent the student voice at Staff-Student Liaison Meetings. The intended purpose of this group is to provide a single group for the entire department (as replacement for all of the others); this is similar to other departments in the Faculty of Science. At this time, access to this group is through request or invitation - with an existing member vouching that you are associated with the school. Currently there are 222 members.

External Grammar:

Because of the complicated relationship within the Facebook groups, use varies between the members. In the over-arching group and the year-cohort groups very specific questions are often asked, and very specific help requested:

Beric: "Does anyone have an idea on what our diagrams are supposed to look like for the Database Systems assessment? We're told to make a conceptual model (in UML form) and a functional dependency diagram (3NF). Not sure if these are the right examples: Conceptual Model: [Provides a URL] Functional Dependency Diagram: [Provides a URL] Thanks in advance :-)"

Sometimes the questions are not about academic content, but rather academic organization:

John: "Anyone doing Advanced Programming, was it tomorrows 10 am lecture that was cancelled?"

Beric: "Did everyone get their mark back for functional programming yet?"

Posts are not confined to academic discussion. In the following, Rorge asks for advice about his phone:

Rorge: "Hey guys quick question... So my Android phone (HTC Desire HD) is currently running Gingerbread as HTC haven't released a Honeycomb, Ice Cream Sandwich or Jellybean update for it, so I did a quick Google and found a couple of custom ROMS to update to Jellybean (4.1.1 I believe) has anyone upgraded using custom ROMS before, if so, is it worth it?"

Traditionally in architecture, geography, social science, etc. when we think of a physical space, we do so as something that exists in three dimensions. Objects and people in physical space are therefore bonded to each other by their proximity and relative orientation, partitioning and even our sense of their presence. These features of physical spaces, give us cues that organize our behaviour in these environments and this in turn imparts a sense of place in the physical world.

In contrast, most virtual spaces (except for virtual worlds) lack these physical constraints, people still interact with each other, they invest time and meaning, and know what interactions are considered appropriate/improper, but this behaviour (this place) is not underpinned or organized by any traditional notions of space – it is because of this, Harrison and Dourish term these kinds of virtual environments as ‘space-less places’ (Harrison and Dourish 1996).

The notion of Facebook year groups as ‘space-less places’ certainly holds truth when they are first created, as the only commonality of the members of these groups (at the time) is that they are potential applicants to the programme; and yet the applicants still develop a sense of the kinds of questions to ask here, how to ask them and to whom to direct them.

However, there is a defining point in time for each of these year groups that

transforms them into something else – the point at which the admin hands over control, removes unsuccessful applicants and the applicants become students in physical attendance at the university. It is at this point that the students start to bring things from the physical environment into this space, the questions relate to assessment, opinions on lecturers, academic timetabling organization, etc. Here, the boundary of the virtual world and the physical starts to break down and blend into each other; Harrison and Dourish term these as ‘Hybrid Spaces’ (Harrison and Dourish 1996).

4.11 Conclusion

Our findings have identified that the students ‘pick and choose’ where they go to find help and support. The particular task that they are working on, the kind of problems that they are encountering, and the physical affordances and social characteristics of different spaces influence their choice. They approach these spaces seeking support for their practice. This is not the formal, scaffolded explanation that might be expected in a classroom setting, nor the individual practices of looking things up in books or on the web. Rather it is the social and community-focused practices that are located in these spaces, this is where they expect to find the *Knowledgeable Friend*, *Safe Asking*, *Nice Guy*, *One step ahead guy*, and *Providers* that were identified and categorised in the CIT study. These spaces, then, become sites of disciplinary practice, and gain meaning as different groups of

students congregate in ‘affinity’ – the aggressive, defensive PBR & IRC, the noisy, social Common Room the supportive and cooperative KITC and The Shed. Each space attracts its own “community” with its own norms. It is in this rich interaction that practice emerges and transforms these spaces into places.

We also see from our findings, that whilst others could attempt to build their own Shed, Common Room, or Facebook groups, they can only do so to try to encourage specific types of interactions to occur. What those spaces will become and how they will be experienced as places, cannot be dictated by the provision of whiteboards, easy-access electrical sockets or other physical affordances, it is the people who will begin to inhabit these spaces after their creation, that will ultimately mould and transform these spaces into places.

Therefore, in response to research question three *how can we characterize the structure of the different places tha student use to support their academic study* the contributions of this study towards this thesis, are:

- We used a method (the unfolding matrix) that helps to capture students’ practice and their use of different spaces.

- The students that go to these spaces have expressed, in their own words, the community that exists in these spaces, the kinds of interactions that occur within them, the physical affordances of these spaces (that they use), and how these spatial features influence where they work and the practice that occurs.
- We characterized the different kinds of learning spaces identified in this way using the Semiotic Social Spaces framework (Barton and Tusting 2005). In these spaces we found ‘defensive’ (but supportive) environments; for example the Peter Brown Room and IRC, a quiet space with expert help (The Shed), and spaces where the students expressed a sense of ownership and ‘real’ work (The KITC). We also characterized a virtual space, the first-year Facebook groups, that transform from ‘spaceless places’ to places of meaning and where you can expect to find help from other students.

Chapter 5 - Closing Material

5.1 Limitations

On Qualitative Inquiry

Throughout this research, we have employed the use of qualitative research studies to investigate the spaces that computer science students use to support their academic studies. Qualitative research is useful when attempting to understand the social reality of individuals and groups. It would be impossible to ‘capture’ these human experiences using quantitative measures. However, these same strengths open qualitative data to criticism for its subjective nature, its origin from single contexts, and that situations, events, and interactions cannot be replicated by others for generalisations to be made with confidence in a wider context.

Because of these criticisms, researchers conducting qualitative inquiries routinely employ the use of *thick* description (making explicit cultural and behavioural relationships and putting them in context), *triangulation* (cross-checking using multiple data sources) and *external audit* (having a researcher not involved in the work to review the process and findings) during their investigations to help demonstrate the trustworthiness of their research. In support of qualitative investigation, several authors have also provided a diverse range of frameworks and definitions to demonstrate credibility (LeCompte, Preissle and Tesch 1993; Maxwell and Joseph A

1992; Kirk and Miller 1986; Lincoln and Guba 1985). These frameworks can be used to support the establishment of trustworthiness in qualitative studies.

Determining Trustworthiness

In this research, we draw on definitions of trustworthiness by Lincoln and Guba (Lincoln and Guba 1985) and utilise frameworks proposed by Miller (Creswell and Miller 2000) and Shenton (Shenton 2004). When conducting qualitative research, Guba suggests four criteria that should be employed by the qualitative investigator:

- Credibility (in preference to internal validity)
- Transferability (in preference to external validity/generalizability)
- Dependability (in preference to reliability)
- Confirmability (in preference to objectivity)

In the subsequent sections, we explain each definition in turn, and demonstrate its application in our work.

Credibility

Credibility aims to establish that the results of the research are believable; it depends more on the richness of the information gathered, rather than the quantity of data. There are many techniques to gauge the credibility of the findings; in this research we apply: adoption of research methods that are

well established, random sampling, triangulation and member checking (Trochim 2006).

In ensuring the adoption of research methods that are well established: in study one (diary), we developed an instrument based on the principles of existing diary studies that had mapped students' use of space in education settings (Ramsden and Carey 2014); for the second part of study one, we modified our instrument and adopted an interview component similar to an existing study from computing education (Fincher, Tenenberg and Robins 2011). In study two (CIT), we utilised an existing dataset that had been collected using methods informed by the Critical Incident Technique (Flanagan 1954), a well-regarded and extensively used set of procedures. For the analysis of this data, we used principles of conducting a Grounded Theory analysis as defined by Glaser and Strauss (Glaser and Strauss 2009) and provided a 'walk-through' of this procedure with our data. The dataset used for study three was informed by a technique known as the 'Unfolding Matrix' (Padilla and others 1996). The presentation and analysis of this data was informed by Semiotic Social Spaces (Barton and Tusting 2005).

We used *random sampling* in two studies to help negate researcher bias in the selection of participants. In study one (diary), 128 out of a cohort of 235 students, across two campuses, participated in the keeping of a diary. In our third study (unfolding matrix), we utilised random sampling for each of the

six interviews that we conducted; these interviews occurred ‘on the spot’ in the environment in which the students were working.

The three separate studies provided *triangulation*; the use of these different methods in concert compensates for the limitations of each individual study and exploits their benefits (each study illuminated a different aspect of our research topic). In particular, the use of the matrices in the third study (unfolding matrix) affirmed our observations from study one that students gradually identify spaces and come to understand their purpose. In this they adapt their use of space - shifting from exploiting rooms that they know about from timetabled classes, to using dedicated disciplinary space. Similarly, the practices that our students identified during their participation in the third study (unfolding matrix), resonated well with our findings from the second research study (CIT).

A limitation of this research is that we used only a limited amount of ‘member checking’ for the data collected. Member checking is where informants are asked to re-read any transcripts of dialogues in which they have participated to ensure that the words match what they actually intended. Whilst we did have transcriptions and tape recordings of all interviews (and we made use of these recordings when interpreting the

transcriptions), we did not re-approach any of our participants with our findings.

Transferability

Transferability is the degree to which the research can be transferred to other contexts. To permit transferability, it is essential that the researcher supplies a highly-detailed description of their situation and methods to allow others to repeat their work (Trochim 2006).

To help address issues of transferability within this research, demographic information is provided for all studies.

In study one, a variety of visualisations are provided to assist the reader in their understanding of some of our findings. For example, the heat map images provide geographical context for the potential differences of space use by first- and second-year students. This was accompanied by background information, about cultural aspects of the institution; for example, the clustering of study bedrooms, common areas of residence within the city and physical proximity of different bars / facilities to academic classrooms.

A limitation of study two (CIT) is that demographic information was unknown to us as we were secondary researchers using an existing dataset;

only information concerning number of participants involved in the study, data collection methods and number of institutions involved were obtainable.

In the third study (unfolding matrix), we presented data concerning the spaces in question to help triangulate our findings; this included: floorplans, background contextual information concerning the spaces, data from websites concerning the spaces' purpose and verbatim text from interview transcripts.

Dependability

The quantitative view of *reliability* is based on the assumption of replicability or repeatability and is concerned with whether a researcher would obtain the same results if they could observe the same thing twice. In qualitative research, we can't actually measure the same thing twice because the social environment is constantly changing and no setting is exactly the same. The equivalent qualitative construct of *dependability* emphasizes the need for the researcher to account for the ever-changing context within which research occurs (Trochim 2006).

To address concerns of dependability, study one (diary) provided an in-depth explanation of the design and use of the diary instrument. This

included diagrams of its design and functionality and the different ways in which it was used (with and without an interview component).

In study two, as well as undertaking Grounded Theory analysis we take the additional step of presenting the findings in a coding scheme table explicitly designed for public consumption, for other researchers to utilise, based on the work of Amabile (Amabile *et al.* 2003).

Study three (unfolding matrix) provides the protocols used for conducting the focus groups to allow other researchers to conduct their own similar studies.

Confirmability

Qualitative research allows each researcher to bring a unique perspective to the work; however, this raises questions about the possible introduction of researcher bias into the studies. *Confirmability* questions how the research findings are supported by the data collected.

To provide confirmability of the work conducted, a number of precautions were taken to help mitigate researcher bias. In the first study (diary), the diary instrument provided a researcher-distant approach for the purpose of identifying the spaces used by students. The artefacts used at interview also

helped elicit a factual response from the participants. The dataset used in the second study (Critical Incident Technique) was collected by an independent researcher. In addition, the method used helps provide mitigation of researcher influence, by providing a factual account of a real situation from the perspective of the participant.

The third study (unfolding matrix), utilised a focus group interview to help mitigate bias from individual students. In addition, the use of the matrix artefacts helped ‘ground’ each interview and facilitated students in making adjustments / corrections during the interview procedure.

In all aspects of this research work, detailed accounts of the data collection methods and the subsequent analytical techniques employed are presented to provide an ‘audit trail’ for the findings identified.

Threats to Validity

The purpose of proving validity is to give support for others to believe in your findings. A key part of demonstrating validity is to consider the ‘validity threat’. A validity threat is an alternative explanation that could be put forward to explain your findings. For example, in our first study, the Diary Study, we asked participants to record the spaces that they use whenever they are working on their project; however, this research approach

depends entirely on the honesty and interpretation of the request by the actual participant – what if they forgot to make an entry? Or perhaps there's certain spaces that they were unwilling to share? Or even they completed their diary entries in bulk at the end of the day. Without the researcher being present, it is difficult to detect variation between participants and therefore account for its impact on our first findings. To address this validity threat, we repeated the research study, but with an accompanying interview component. This provided two benefits: the remoteness of the researcher, through the use of the diary exercise, helps to combat what Maxwell (Maxwell and Joseph A 1992) describes as one of the common threats to validity, researcher bias, whilst the interview component helps to provide context, calibration and confirmation to help address the concerns listed above.

If we consider the second study, the Critical Incident Technique, the use of a pre-existing dataset is a concern - we have limited access to the demographics, knowledge of the researcher's interview approach, reactivity of the participant due to the interview context, or even the environment. Similarly, our analysis of the data and consequently, our findings, could make us vulnerable to accusations of trying to 'fit' the data to our own pre-existing judgements. In contrast, our research approach could also defend us against these concerns of validity. The use of a pre-existing dataset removes

our unwanted biases from the dataset and a grounded theory analysis helps to prevent pre-existing judgements impairing the work - appropriate use of grounded theory should yield findings that are 'grounded' by data. It is for the purpose of addressing threats to validity as to why we provide evidence of our application of grounded theory at each stage of the analysis.

In contrast with the earlier two studies, the Unfolding Matrix utilizes data that was gathered with the principle researcher's direct involvement. As such, all of our previous concerns of researcher influence could apply. Validity threat questions could include, "did the researcher 'cherry pick' parts of the discussion?" or "did the use of random sampling mean that the findings only represent the views of a self-selected group of people?" or, "by repeating the interviews in each space only twice, what groups who might use the space at different times, may have been excluded?". These are fair concerns and it is possible that the interview data is vulnerable to this. However, this study was purposefully the final study that was conducted for this research, the other two studies help to provide some degree of triangulation for our findings. Similarly, the design of this research study purposefully avoids the use of just interview data; instead, the environment is presented by the use of thick description, floorplans and in some cases, photographs. In addition, the underpinning use of Gee's framework on

semiotic spaces (Walker 2006) ensures that there is consistent application of the research approach for each space.

5.2 Conclusions

We have shown in this research a complex ecology of different types of learning spaces that our students use to support their academic study. This rich ecology supports the thesis that *space* is an important factor in affording student engagement and learning. To summarise our findings, I will address each of the three research questions posed at the start of this work.

Study One (Diary Study) - What spaces do computer students utilize outside of formal activity?

As we see in the literature, ‘spaces’ and ‘places’ have a number of distinct features. Spatial features include: relational orientation, proximity and action, partitioning and presence (Harrison and Dourish 1996). How a space is perceived is experiential to the individual and adorned with personal experience and emotion (Tuan 1977). In contrast, ‘place’ is a purely human notion, it is made by people appropriating and living within the physical environment. Its features include, the investment of meaning and understandings of behavioural appropriateness, cultural expectations and ritual (Harrison and Dourish 1996).

These theoretical constructs were represented in our data. We used a diary instrument to map the spaces that both first- and second-year students use

for academic work. Some of the spaces that we identified were formal teaching spaces; however, their use by the students was exploitive and outside of scheduled time. Some of them were domestic spaces (study bedrooms) and here we saw a sense of ownership within these spaces; other students would avoid going to them, unless specifically invited. Finally, we identified that students would use cafés and bars that were in close proximity to them; here, group-work frequently took place and served as a ‘neutral-ground’ for the first-year students.

There was a striking difference between the first- and second-year usage. First-years use formal spaces that are immediately visible to them – the Library, rooms they have been taught in, cafés. Second-years use spaces that are not immediately obvious; for example, the Common Room and the Peter Brown Room. This indicates growth of community and “insider knowledge” – i.e. you come to find out about these spaces during your first-year of study.

Study Two - What are the practices that students engage with when they are studying computer science?

For this second study, we used a research method originating from psychology (the Critical Incident Technique), to capture data concerning

student practice outside of formal study. Informed by a Grounded Theory analysis, we uncovered a number of different practices that students use when learning to program.

Some of these practices were personal to the individual, these included ‘code fragment’ - using someone else’s line of code to get by, without understanding its function, or ‘taking it apart’ - to see a line of code’s effect on a program by its removal. These practices also suggested disciplinary development, from ‘shotgun debugging’ - a basic strategy of randomly changing lines of code in the hope of resolving an error, to ‘stepping through the program’ – tracing its function line by line.

Student practice outside of the classroom environment was not just comprised of personal practices, students regularly (17 participants out of 29 interviews) sought help from others to support their studies. The type of help asked for and received varied. Sometimes these were situations like ‘asking a knowledgeable friend’ – a person who is relatively close to the individual in question, but likely to have the answer. In contrast, ‘safe asking’ – was going to a close friend / family member because they are non-judgmental, even if they weren’t the most knowledgeable.

Study Three - How can we characterize the structure of the different places that students use to support their academic study in our home institution?

For this third study, we used a matrix artefact developed during a focus group interview to capture data concerning student practice and space use outside of formal study. Informed by a framework, known as Semiotic Social Spaces (Barton and Tusting 2005), we characterised six different kinds of spaces provided by a computing department. We did this, because unlike many of the other spaces that we identified in this work, we (as a department) provide these spaces in order to attempt to support particular kinds of practice.

Using this framework, we discussed their physical design, the intention for constructing these spaces, and the student's experience of these spaces.

Our findings show that the students 'pick and choose' where they go to find help and support, and this is influenced by a number of different factors: the task that they are working on, the kind of problems that they are encountering and the physical affordances and social characteristics of that space.

When students go to these different spaces, to support their learning, they have clear expectations of the help and support that they will find there, and also understand what participation in those spaces requires. Their participation in these spaces helps add to its 'collective memory' and builds

up a history of shared experience / ritual. As Erickson suggests “ritual is useful because it connects three important elements of human interaction: participants, repeated set of actions, and artefacts or spaces.” (Erickson 1993, p.402). These spaces, then, become sites of disciplinary practice, and gain meaning as different groups of students congregate in ‘affinity’ – the aggressive, defensive PBR & IRC, the noisy, social Common Room, the supportive and cooperative KITC and The Shed. Each space attracts its own ‘community’ with its own norms. It is in this rich ecology, *practice* emerges.

Thus, when we see these different learning ‘spaces’ as ‘places’, we find that the kind of interaction seen in the Peter Brown Room (for example) cannot simply be transferred to the Shed, both exist in the own intimate combination of their spatial affordances and the meaning invested into them as places.

5.3 Future Work

As indicated in this thesis, computer science students are readily adopting the use of online resources and communities to support their academic study. Whilst we briefly touched upon the use of virtual communities, such as the use of local Facebook groups in Study Three, the boundaries between digital and virtual spaces remain largely unexplored in this research.

A limitation of this research, was that we quickly encountered difficulty in analysing the interactions occurring in these kinds of spaces. First, interactions occurred at scale, with students being able to address entire parts of the student cohort. Second, interactions occurred simultaneously across multiple geographical boundaries, some between different Facebook groups, whilst others took place in the physical and virtual world.

Although we were able to visualise the interactions in these spaces, including those that spanned multiple virtual groups, we were unable to determine whether those interactions were related to each other. As a consequence, we were still confined to researching student interactions within isolated localities.

It is therefore clear that researching students' use of virtual spaces is an area that is fraught with difficulty; however, we believe that to continue our research, we must venture into this domain. Whilst there are many different

areas that we could research within these spaces, for future work, we wish to explore methods, specifically mapping diaries that visualise the simultaneous use of physical and virtual spaces during academic study.

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