An Investigation into Real-time, Small-Group, Student-Centred Engagement on Mobile Devices in Lectures.

by

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Abstract

This thesis investigates the engagement of students in the lecture environment, with a student-centred approach, using mobile devices. The lecture is not, and cannot be, a one-size-fits-all solution to the delivery of content due to the globalisation of university education. The lecturer and student body are drawn from many cultural identities and bring with them, different knowledge, skills, abilities and other attributes, in addition to their social and cultural norms. For many students the ability to engage, or remain engaged, in a lecture is beyond their own ability, or that of the lecturer, even with the best of intentions from both. If the lecturer and the student cannot provide, or maintain, the necessary engagement the only remaining avenue for engaging the student in the lecture content is their fellow student; someone who is, or should be, in attendance at the same lecture. The solution proposed in this thesis, *GroupNotes*, uses mobile devices that are likely already in the possession of the student to provide silent, fast, written interaction, and allows small groups of students to cooperate in meeting the shared goal of increasing their own knowledge. *GroupNotes* allows each group member to dynamically limit their real-time exposure to the content generated by the group without affecting the ability of any other group member to do the same; while at the same time making available for review, after the lecture, a full capture of all content generated during the session. The results from testing *GroupNotes* suggest that students, during the lecture session, prefer collaborative to individual note-taking, sharing virtual workspaces in a quiet environment to tangible workspaces in an audible environment, and to sharing spatially separated workspaces over a constrained common workspace, either physical or virtual. The students also report being more engaged with collaborative than with individual note-taking, and when sharing spatially separated workspaces over sharing a common workspace. *GroupNotes* testing also provided results that indicated a positive impact on engagement outside of the lecture session in two areas. The use of *GroupNotes* encouraged students to revise their lecture notes, and to discuss them with at least one other person, however a third area that of increasing preparation before the lecture, was not confirmed. The contribution of this research is that it identifies a student preference for collaborative over individual note taking during a lecture and that this cooperation takes place in a spatially separated virtual environment. With access to this form of cooperation, students reported increased educationally meaningful engagement both during the lecture and in post-

lecture activities, over their current practice of note taking in isolation. The capability of modern mobile device technology, combined with the desirability of these devices for use in everyday activities, afforded an opportunity to examine an alternate method of engaging students in those lectures where neither the individual student, or the lecturer, is capable of providing the required level of engagement. The findings from this research invite further investigation to determine where this type of interaction is most effective; technical or social science disciplines?, local or foreign students?, paired or larger groups?, or all disciplines evenly? A further direction for research is to determine what use can be made of the ready availability of the notes taken by students during a lecture. How can this information be used to inform the lecturer of their success, or otherwise, in achieving the knowledge transfer they are attempting.

Declaration

I certify that this thesis does not incorporate without acknowledgment any material previously submitted for a degree or diploma in any university; and that to the best of my knowledge and belief it does not contain any material previously published or written by another person except where due reference is made in the text. Signed Dated

Mark Damian Reilly

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Undertaking a PhD is both a great privilege and a luxury. The opportunity to immerse myself in an area of great personal interest while at the same time working with incredibly intelligent, talented and hard working people is an experience for which I shall be forever grateful.

In my Honours year I was faced with the choice of selecting either of two topics to complete my coursework. One of them I was really not keen on, the other was a new area I knew nothing about, and was being delivered by a new lecturer to the school, who I knew nothing about. In making my choice to go with the unknown I made one of the best choices of my life, and certainly the best of my academic life. Dr Haifeng Shen delivered Computer Supported Cooperative Work (CSCW) and by week 2 of the semester I knew this was the area, and the supervisor, for me.

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"My brain, and my heart, are happy"

Publications

The following publications are attributed to the research conducted as part of this thesis or material presented within this thesis. However, where the latter is the case the material has been re-examined and revised as necessary.

Publication 1 relates directly to the initial research idea and relates to Smartphones while publications 2 and 3 are related to the design and implementation of a Tablet centric design. Publication 4 is a result of research discussing the educational rationale of our GroupNotes project while Publication 5 is the design of the back end to the project. Publication 6 presents the GroupNotes user interface. Publication 7 presents selected results from initial testing while Publication 8 presents results comparing spatially separated workspaces to common workspaces. The final publication 9 is an extension of the conference publication 8.

1. Reilly, M. and Shen, H. (2011). GroupNotes: Encouraging Proactive Student Engagement in Lectures through Collaborative Note-taking on Smartphones. *in* Proceedings of the 9th International Conference on Computer Supported Collaborative Learning. The 9th International Conference on Computer Supported Collaborative Learning. pp. 908-909.

2. Reilly, M. and Shen, H. (2011). The Design and Implementation of the Smartphone-based GroupNotes App for Ubiquitous and Collaborative Learning. *in* Proceedings of the 6th International Workshop on Ubiquitous and Collaborative Computing. pp. 46-55.

3. Reilly, M. and Shen, H. (2011). Unobtrusive Student Collaboration during Lectures with Smartphones. *in* Proceedings of the 6th International Workshop on Ubiquitous and Collaborative Computing. pp. 56-65.

4. Reilly, M. and Shen, H. (2011). Shared Note-taking: A Smartphone-based Approach to Increased Student Engagement in Lectures. *in* Proceedings of the 11th International Workshop on Collaborative Editing Systems.

5. Shen, H. and Reilly, M. (2012). Personalized Multi-user View and Content Synchronization and Retrieval in Real-time Mobile Social Software Applications.

in Journal of Computer and System Sciences, 78(4), pp.1185-1203. [online]. http://dx.doi.org/10.1016/j.jcss.2011.10.008.

6. Reilly, M., Sambrooks, L., Shen, H. and Wilkinson, B. (2013). GroupNotes on Tablets: Sustaining Diversity in Social Learning through Shared Individual Workspaces. *in* Proceedings of the 13th International Workshop on Collaborative Editing Systems.

7. Reilly, M., Shen, H., Calder, P.R. and Duh, H. (2013). Understanding the effects of discreet real-time social interaction on student engagement in lectures. *in* Proceedings of the 25th Australian Computer-Human Interaction Conference: Augmentation, Application, Innovation, Collaboration. pp. 193-196.

8. Reilly, M., Shen, H., Calder, P.R. and Duh, H. (2014). Towards a Collaborative Classroom through Shared Workspaces on Mobile Devices. *in* HCI 2014. British Computer Society. HCI 2014: The 28th British HCI Conference. Southport, UK. Sep 2014.

9. Reilly, M., Shen, H., Calder, P. and Duh, H. (2015), Sustaining cognitive diversity in collaborative learning through shared spatially separated virtual workspaces on mobile devices, in T. Wyeld, P. Calder and H. Shen, eds, 'Computer-Human Interaction. Cognitive Effects of Spatial Interaction, Learning, and Ability', Vol. 8433 of Lecture Notes in Computer Science, Springer International Publishing, pp. 171-193. URL: http://dx.doi.org/10.1007/978-3-319-16940-89

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Chapter 1

Engagement of Undergraduates during Lectures

The issue this research addresses is the lack of engagement by some undergraduate students in lectures and whether the use of mobile devices such as Smartphones and Tablets can be used to increase engagement during lectures when applied from a student-to-student perspective.

Why is there a difference in the attendance and engagement of students during lectures? Some students turn up, some do not, some pay attention for the entire lecture, some for a brief period or two, while others come to a lecture and play computer games, surf the internet, charge their mobile devices, or fall asleep. The expectation from teaching staff is that lectures, which account for approximately half of the scheduled staff-to-student contact time, are an important teaching resource and the information provided during those sessions should not be wasted.

To understand the problem a discussion of the role of the university, and the student, in relation to undergraduate education is necessary. From the understanding of the purpose of the university it is important to identify the teaching and learning processes that contribute to the education of the student and who is responsible for each. With regard to learning, the fundamental key is engagement; the individual is responsible for constructing their own knowledge from available resources, including within themselves.

1.1 University Education

What is the purpose of a university?

The purpose of a university is, at least, threefold; to produce graduates, to produce post graduates and further, to produce research, expert opinion, and cutting-edge tools and techniques. At the undergraduate level it is about producing graduates with certain attributes including learning, and learning how to learn.

This research is only concerned with undergraduate education and therefore requires an understanding of what is expected of a graduate. In the state of South Australia there are three universities offering undergraduate degrees and each provides a summary of the attributes expected of a graduate. Generally these can be reduced, in relation to learning, to the following. The graduate will have learned domain specific knowledge and be able to apply that knowledge, and in addition will have equipped themselves with the abilities required for lifelong learning; they will have learned how to learn.

1.1.1 Undergraduate Level Education

Graduate Qualities

The university promotes the acquisition of certain 'graduate qualities' by the student, including the means to continue life-long learning, not just for their career, but also as part of being a productive member of the community. Of the three universities in South Australia providing undergraduate education each identifies that the end result of the education process is that the graduate is knowledgeable and can apply that knowledge (Adelaide University, 2015; Flinders University, 2015; University of South Australia, 2015). Highlighting the Graduate Attributes of these universities, specific to the ability to construct and apply knowledge, provides the following:

Flinders University produces graduates:

> **who are knowledgeable**
> We expect our students to develop an extensive and well-founded knowledge in their field of study. This includes the ability to acquire and understand, using current technologies and effective learning strategies, information and ideas that underpin this knowledge.
> **can apply their knowledge**
> We expect our students to develop the ability to use their knowledge to plan, to analyse, to think critically, logically and creatively, to reflect upon and evaluate ideas, options, and potential solutions to problems, and to make and implement decisions.
> **who can work independently**
> We expect our students to take responsibility for, and become self-reliant in, their learning and their work. This includes organising their activities, prioritising their tasks and managing their time productively. It also includes recognising that the world is dynamic and changing, and therefore being prepared to take responsibility in the years ahead to review, update and adapt their knowledge and skills.

The University of Adelaide produces graduates who have:

> **Deep discipline knowledge**
> accredited or validated against national or international standards (for relevant programs)
> **Critical thinking and problem solving**
> based on empirical evidence and the scientific approach to knowledge development

A graduate of the University of South Australia:

> Operates effectively with and upon a body of knowledge of sufficient depth to begin professional practice.
> Demonstrates an understanding in broad outline of a whole discipline or professional area (concepts, theories, proponents) including a knowledge of the boundaries.
> Is prepared for life-long learning in pursuit of personal development and excellence in professional practice.
> Can locate, evaluate, manage and use information in a range of contexts - i.e., be information literate.
> Can understand the limitations of, and have the capacity to evaluate, their current knowledge.
> Can understand and accept personal weaknesses, strengths and preferred learning styles, have knowledge of a range of learning strategies, and take responsibility for their learning and development.
> Is an effective problem solver, capable of applying logical, critical, and creative thinking to a range of problems.
> Can gather, evaluate and deploy relevant information to assist problem solving - i.e., analysis and synthesis.

The attributes and abilities listed reveal that learning is high on the list of expected outcomes, both discipline specific and as a continuous, life-long endeavour.
What then is learning?

1.1.2 What is Learning?

The New Oxford Dictionary (2010) defines learning as "the acquisition of knowledge or skills through experience, study, or being taught" and (Boyd, Apps et al., 1980) emphasise the role of the person in whom the change occurs, or is expected to occur. "Learning is the act or process by which behavioral change, knowledge, skills, and attitudes are acquired"

There are many different theories on how we learn. For the purpose of this research, a subset of constructivism (Munari, 1994), known as social constructivism (Cole, V.,

Scribner and Souberman, 1978), is the theory that identifies that knowledge is constructed in the individual as a result of shared interactions with others, including peers. As this research involves applying student-to-student interaction in a learning environment it is important to identify that the current research is based on established principles.

The Constructivist Theory of Learning

Constructivism

The theory of constructivism is generally attributed to Jean Piaget (Munari, 1994) who describes learning as the adaptation of new knowledge and meaning through either assimilation or accommodation to allow us to cope with change in our environment. The individual has a schema, or cognitive framework, of a particular area on which to base any new information they encounter. This schema provides a mechanism to allow new information to be processed in relation to what is already known about a specific area, instead of against all knowledge retained by the individual.

The incorporating of new knowledge into an existing schema is known as either accommodation or assimilation. Accommodation is the term for the process of an individual creating new knowledge when faced with information or an experience that contradicts their internal representation of the world (schema) and is required to alter this representation. Assimilation is defined as the incorporation of new information or an experience into an already existing framework without changing that framework.

An important aspect of learning is that the knowledge of the individual is validated against that of another. Is the individual right to dismiss new information in the current circumstance? What do their peers think of the new knowledge, is it valid, trustworthy etc. or is it right to dismiss it. Alternatively, how are others fitting this new knowledge into their existing framework?

Social Constructivism

An extension of constructivism, known as social constructivism, appears most relevant to our concept of learning as our 'knowledge' is defined in reference to that of our community, our peers, teachers, social and community leaders. Social Constructivism describes the learning that takes place in the individual as a result of the interactions of the individual within a group, and the shared meaning that is created. Other research to validate this approach are Vygotsky's social learning theory which indicates that 'the development of cognition in an individual is constructed through interaction with others; social interaction is therefore critical to this development' (Cole et al., 1978).

Example 1.1.
Student A is watching a lecture and taking notes. At the 10 minute mark of a 2 hour lecture they are presented with new knowledge which does not fit in with their internal representation (schema) of the subject being delivered. At this point there are several options available:

1. Dismiss the new knowledge as being wrong
2. Assume they have misheard the lecturer and continue with a faulty assumption on what was said
3. Take on board the new content and try to integrate it into their current understanding of the subject

In cases 1 and 2, Student A would benefit from being able to ask a question at this point to clarify their understanding of the content just delivered. In many lecture environments this is not permitted at all, and in others, questions must wait until the end of the lecture, or some other time of the lecturers choosing. Student A has just wasted almost 2 hours of their time either ignoring the new content, or trying to reconcile it into their current schema. If they were able to ask a question at the appropriate moment, as is the case in a tutorial session, then this time may not have been wasted. As it stands they must now clarify the content delivered and then accommodate or assimilate this new information at a later time.

Case 3 is the ideal, knowledge is accepted and either assimilated or accommodated. Even this scenario may be enhanced by external validation, by peers or the lecturer, that their understanding of the just delivered content is accurate. In this case the rest of the information being delivered in the lecture can now be constructed into knowledge, until another new piece of information is delivered which may or may not fit their internal world view, and then there are these same three scenarios to consider. ■

With respect to Example 1.1, Cases 1 and 2, by asking a question at the relevant time also provides benefit beyond the individual student. As part of a social structure we also learn from others' failure. The question is useful to others if it demonstrates a faulty understanding that matches their own. The opportunity to reassess their own understanding with further input from the lecturer, and possibly others, is now available. If the question posed shows an understanding of the content delivered, others who have constructed that same knowledge have now had their learning externally validated.

This *social* learning paradigm is familiar to students as it is how they have learned much of their way in the world to date. They construct new, or reinforce existing, knowledge and make meaning of this information through interaction with others in their community, including family, friends and other persons considered important, such as teachers.

This research is concerned with the individual's acquisition of knowledge in an educational setting. Blooms Taxonomy established the objectives for education in 1956.

Bloom's Taxonomy, more formally, the "Taxonomy of Educational Objectives: The Classification of Educational Goals"; (Bloom, Engelhart, Furst, Hill and Krathwohl, 1956) identified Knowledge, Affective and Psychomotor as the three domains in education however this research is only concerned with the cognitive domain comprising knowledge, comprehension and critical thinking. The Cognitive domain listed the six levels of processing as *Knowledge*, *Comprehension*, *Application*, *Analysis*, *Synthesis*, and *Evaluation*. Each process assumed mastery of the previous process in order to progress to the next as they were assumed to be in increasing order of complexity or required ability. Knowledge, in the context of this classification "involves the recall of specifics and universals, the recall of methods and processes, or the recall of a pattern, structure, or setting" (Bloom et al., 1956). The most important aspects of learning involve being able to use the 'knowledge' that has been acquired; the processes from level 2 to level 6, *Comprehension* through to *Evaluation*.

The revision of Bloom's taxonomy (Anderson and Krathwohl, 2001) was completed in 2001 and Krathwohl (Krathwohl, 2002) identifies the new terms and revised order of the six processes in the cognitive domain. *Knowledge* has been renamed to *Remember* and involves "Retrieving relevant knowledge from long-term memory". The remaining processes are *Understand*, *Apply*, *Analyze*, *Evaluate*, and *Create*. The *Create* process - putting elements together to form a novel, coherent whole or make an original product, is the new name for the original *Synthesis* process. *Create* is now regarded as the process with the highest order of complexity and required ability to perform and has exchanged places with *Evaluation*.

The revised taxonomy also identifies that the cognitive processes are no longer assumed to be a hierarchy and rely on mastery of a level prior to moving to the next. The general progression of learning will follow the order outlined above however it is also accepted that elements of each process are able to occur out of order. Viewing an example from a peer, before a complete knowledge and understanding of the underlying principles, does not mean that applying the knowledge is not possible. It may be that applying incomplete knowledge, and understanding the results of that application, enables the individual to more readily construct their own knowledge.

Learning consistent with the expected capabilities of an undergraduate student is "the acquisition of new knowledge or the modification of existing knowledge and involves the reconciliation of multiple perspectives, including that of the peers of the learner" (Koschmann, 1999). Further, it involves the retention of this knowledge internally and the ability to act on it.

In order to understand why students are not engaged in lectures it requires an

understanding of the specific domain and the characteristics of both the environment and the actors. The environment is a university lecture theatre which has unique constraints on the actors, both lecturer and students.

1.1.3 How is learning accomplished?

The education process of an undergraduate student gaining knowledge, or learning, while at university consists of two different elements. Firstly there is a 'teaching' element where information is delivered through means such as a lecture, tutorial or a set of readings to the individual and secondly, there is the 'learning' element where that individual must learn, that is, actively capture the information presented, make sense of it, and have it available internally for future use. The important point to note here is that the individual is responsible for capturing the information and creating knowledge from it.

The teaching element in undergraduate education in university consists of two forms of instruction; the 'social' paradigm where questions and interaction between teaching staff and student, as well as student-to-student, is encouraged. The second form of instruction is the lecture where, in general, the student works in isolation, no collaboration with others, and attempts to process the information delivered to them by the presenter, or content expert, in an attempt to build the relevant knowledge for themselves.

The social, or more interactive methods of teaching, consist of various types of interaction and delivery such as tutorials, lab sessions, workshops, discussion groups forums and wikis as well as individual and group consulting, and group work sessions. The common factor in these sessions is that interaction is expected and encouraged.

Interactive Sessions

Interactive sessions can be classed as either synchronous or asynchronous. The expectation of immediate interaction exists in methods such as tutorials, lab sessions, consulting, and group work sessions, while a forum, or web-based discussion group, would not normally provide this real-time capacity.

A Tutorial will involve an instructor led discussion where specific information is addressed with the intention of having the individual student move beyond the 'remember' stage in the cognitive process. The objective is for the student to be able to understand the new knowledge in its parts, and as a whole, leading to being able to correctly apply that knowledge and evaluate its suitability for a given purpose. Finally it is to be able to create new knowledge based on this recent and pre-existing knowledge contained within the individual. In this environment all six cognitive processes are able to be applied to the content being discussed. The session does not have to

rely on the teaching staff to lead the discussion but may incorporate, or encourage, peer interaction to provide multiple opportunities for the individual to involve all six cognitive processes for the content under discussion.

A consulting session is generally a one-on-one session between a member of the teaching staff and the student to enable the student to progress from an area of difficulty. It can also be a group session where students with the same area of difficulty, either as individuals, or all working as a group, are able to gain an insight from a member of the teaching staff to progress their understanding.

A lab session has the same objectives as a tutorial but will add the element of using physical artefacts. The knowledge gained from these sessions, depending on the specific field of study, may include not only the knowledge of how to choose the correct equipment or tools for the job, but also how to safely and skillfully use those devices.

Real-time interaction is not usually available in a forum, or web-based discussion area, created for discussion of specific content or an area of interest however it can involve synchronous communication if organised between the participants.

These deliberately interactive teaching methods typically account for approximately 50% of staff to student formal contact hours, with the remaining time made up of lectures that may, or may not, be interactive.

Non-interactive sessions

Non-interactive sessions at university are the lecture. Not all lectures are non-interactive but there is not the expectation of personal interaction occurring, as is the case with the other methods described above.

In the context of a university, a lecture is an educational talk on a specific topic given to students for the purpose of instruction, or the provision of information. The lecture provides a uniform delivery of information to any size audience and can include information that is not readily available, such as from unpublished material by the lecturer. The experience, delivery skills, knowledge of, and passion for, the content being delivered by the presenter all impact on the engagement of the students attending the lecture.

Two types of lecturing occur; interactive, or non-interactive (didactic). Lectures can, and many do, encourage interaction during the lecture through various methods. An example is by allowing questions at the correct teaching moment and providing sufficient explanation in the answer. Further examples include activities such as short quizzes, peer review (Mazur, 1997), and Think/Pair/Share exercises (Lyman, 1987) which encourage engagement by the student in their own learning.

The non-interactive type of lecture, referred to as didactic, consists of a one-way flow of information from the lecturer to the student and generally does not stop to

allow for questions, which must wait until the end of the session. This is the type of lecture that students have the most difficulty with as the lack of interaction can lead to disengagement with the lecture content in a short time-frame. Only 4-8 minutes of pure factual lecture can be tolerated before the brain seeks other stimuli either internal (e.g., daydreaming) or external (Who is that walking down the hall?) (Perry, 2000). Bligh's claim is that 10 - 15 minutes in a passive situation such as a lecture theatre (Biggs, 1999) is the point at which attention span sharply decreases due to a lack of interaction. If a student cannot ask the lecturer (Hitchens and Lister, 2009) or their peers critical questions at the right time, the 'teaching moment', to reconcile their own understanding they may lose interest and find other ways to occupy themselves, such as sleeping, texting, general web surfing, getting up and leaving, or simply not bothering to attend at all (Hitchens and Lister, 2009).

It is not just the didactic style of lecture that has problems with student engagement. Even with the best venue, interesting content, and engaging lecturer, the student may still fail to engage due to their own personal characteristics. The global nature of, and much greater access to, tertiary education, means that the students and teaching staff have much greater diversity than in the past. The one-size-fits-all lecture is no longer a reasonable assumption to hold.

The lecture is not one-size-fits-all

The reception of a lecture is subject to four variables; the content, the venue, the lecturer and the student.

Content

The content being delivered is for the benefit of the students, however the students will each have their own idea about that content and their own willingness and ability to convert that content into their own knowledge.

- Does the student have an interest in, or see a reason for, the content being delivered.
- Is the work too easy?
- Is the work too difficult?

Venue

The venue in which a lecture is delivered is subject to many variables:

- Is the venue a small intimate setting for 20 where each person is able to be seen and heard, or is it a room for 300 where a student feels part of an anonymous mass?

- Does the shape of the venue promote a 'sage-on-a-stage' atmosphere leading to the feeling that the student is attending a performance and leading to a passiveness in the audience?
- Is there sufficient light to be able to write notes. Is there too much light so that lecturer content on display cannot be viewed clearly?
- Can the lecturer be heard clearly? Can other students' questions be heard when asked?
- Is the venue too hot or cold?
- Are the seats and writing surfaces clean and usable or dirty, smelly and covered in chewing gum?
- What is the availability of technology? Are facilities available to deliver content in an alternative manner e.g., a guest lecturer delivered live from a remote location, or a short video highlighting a specific example?

Lecturer

- Are notes provided? Are they partial or full? Are they supplied prior to the lecture to enable early viewing and planning a note-taking strategy?
- Is the pace of delivery sufficient to present the required amount of content in sufficient depth?
- What is the style of delivery - didactic? Open to questions immediately, or only after the lecture?
- What is the level of interaction permitted?
- What is the level of interaction encouraged?
- What level of expertise in the content is present in the lecturer?
- Does the lecturer have a passion for the content being delivered?
- What is the background of the lecturer? What is their level of language fluency? Do the cultural and social influences determine the examples they provide seem relevant?
- Do they use available technology appropriately?

Student

The student body in an Australian university is made up of many different nationalities bringing their own social and cultural diversity, and attitudes toward interacting with the teaching staff. Humans have individual learning styles and strategies. "Learning and studying are always influenced by the students' prior knowledge, concepts of learning, foci of interest and motivation" (De Corte, 1995).

- Is it normal, or even acceptable, to ask questions of the lecturer?
- Are they reluctant to ask a question in public for fear of ridicule?
- What is their level of interest and enthusiasm for the topic?

- How strong is their work ethic?
- What is the level of their cognitive ability?
- How strong is their fluency in the language used to present; both oral and written?

Even with the best efforts of the lecturer and the student, the lecture as a tool for providing information, may still fail to engage all students who should be in attendance.

Why is the lecture important?

The lecture component, the teaching element, may account for 50% of the formal contact hours between staff and students for a topic. If this time is not used effectively the student is at a disadvantage to attain the required level of knowledge.

The purpose of the university at undergraduate level, with regard to the ability to learn, is to provide an environment where the teacher is able to teach the student to learn and where the student is able to learn. Following on from this, the teacher is able to encourage the student to learn how to learn in an independent fashion, beyond being directed by others what to learn and where to locate the appropriate information sources. The student gains the necessary skills and and is able to locate their own sources of information and assess the value of the information they provide.

The next section illustrates the importance of engagement to the process of learning.

1.2 Engagement

1.2.1 What is Engagement?

Student engagement has been defined, and redefined, over time. A recent definition is "participation in educationally effective practices, both inside and outside the classroom, which leads to a range of measurable outcomes" (Kuh, Kinzie, Buckley, Bridges and Hayek, 2007). Another definition is "the time and effort students devote to activities that are empirically linked to desired outcomes of college and what institutions do to induce students to participate in these activities" (Kuh, 2009). The Australian Council for Educational Research (ACER) in the 2009 Australasian Survey of Student Engagement (AUSSE) provided the following statement: "student engagement is defined as students' involvement in activities and conditions that are linked with high-quality learning. A key assumption is that learning outcomes are influenced by how an individual participates in educationally purposeful activities. While students are seen to be responsible for constructing their own knowledge, learning is also seen to depend on institutions and staff generating conditions that stimulate student involvement." (Radloff, 2010)

There are many high quality learning opportunities available at a university; anything from membership of a committee, or representative board, through to world leading research in an emerging field. There was a need to constrain the scope of this research and therefore a requirement to provide a specific definition of engagement that is to be used. The definition of engagement as applied to this thesis is "students involvement in activities that are linked with high-quality learning and directly related to attending a lecture, and engaging with the lecture content before, during and after the actual lecture session."

Examples of behaviour and activity in this definition of engagement would include activities such as:

- Reading the recommended texts prior to the lecture or completion of required tutorials.
- Actively listening and taking notes, asking questions where permitted and answering questions as required during the lecture.
- Reading of the notes taken during the lecture and rewriting those notes (making notes) and discussing or sharing those notes with at least one other person after the lecture. It may also include viewing parts of, or the entire lecture, again, or further reading to clarify any content delivered which has not been adequately understood and retained.

1.2.2 What does engagement look like?

Engagement with the lecture content is an easy concept to grasp. The individual is actively involved in the capture of the information being delivered as well as the knowledge expected to be attained, and is converting this information into knowledge that can be retained and acted upon. Less easy to grasp is what engagement actually looks like to the lecturer and to other students.

Engagement is difficult to determine because of the different styles of learners. Consider the following scenario:

Example 1.2.
A typical class will consist of the following four types of students:

Student A sits in the class, does not take any notes but is not doing anything obviously unassociated with engagement such as sleeping, internet surfing etc.

Student B writes notes continuously throughout the entire lecture.

Student C also writes notes continuously throughout the entire lecture.

Student D listens attentively and makes varying amounts of notes at different times during the lecture.

How is it possible to determine the level of engagement of each individual based on their level of activity only within the lecture environment?

Student A did not take any notes, but may not have needed to. The pre-reading for the topic was completed and understood and they just attended the lecture to have confirmed that the content just delivered agreed with their existing knowledge, or was able to be accommodated or assimilated easily during the lecture.

Student B did no pre-reading and will not look at the notes again except perhaps prior to an exam.

Student C reads their notes and selectively does further research on areas which are unclear.

Student D does the same as Student C; reads their notes and selectively does further research on areas which are unclear.

For most observers it would appear that Student A was not engaged with the topic while Student D was most engaged, with a combination of note-taking and listening. Were Students B and C engaged? They were certainly busy during the lecture but were any of the higher order cognitive learning skills involved? Student C performed activities linked to these higher order skills at a later time but Student B did no further work on that content at all. ■

Determining engagement is a difficult proposition because it does not just involve being busy during the lecture. Student B from the Example 1.2 may not have been engaged in the content being delivered at all if the notes being taken were not accompanied by any understanding – just verbatim speech to text from the lecturers delivery.

A student who already has prior knowledge of the lecture content and has completed all expected pre-reading for the lecture may not need to take any, or only minimal notes, during a lecture because they already have the knowledge required. From an outside perspective they may appear to be as disengaged as another student who has not done any reading at all and does not have sufficient knowledge to understand what is important to take notes on. The student who takes minimal notes to identify sections which did not make sense and does review those areas post-lecture may appear less engaged than the student who is very busy student taking copious amounts of notes throughout the entire lecture, but never revisits those notes.

The individual differences of the students in terms of existing knowledge, motivation for being there, cultural and personality differences, and preferred learning style, all impact on the perceived level of engagement that the lecturer, and other students see.

In general, the taking of notes and the answering or asking of questions, along with a general sense of the student being alert, is seen as engagement during the lecture.

1.2.3 What does non-engagement look like?

As mentioned in Section 1.2.2, it is difficult to determine if a student is truly engaged or not however it is much easier to see if they are not engaged. Failure to attend the lecture is a fair indication of a lack of engagement, but there are valid reasons for non-attendance such as work commitments and timetable clashes. The most obvious indication of non-engagement is the student who attends the lecture but spends some, or all of the time, on their phone/tablet/laptop playing games, watching video, listening to music, or checking in with social media. As a colleague mentioned when discussing students not engaging in the content during a lecture, 'Nobody looks down at their waist and laughs if they are paying attention to the lecture'. Other students are constantly talking and laughing while others turn up and promptly go to sleep.

1.2.4 Why is engagement important?

A university is many things; a place of teaching and learning, of research, and of expert and informed opinion however, at the undergraduate level, the purpose of the university is to have students learn, and learn how to learn. The capture of information and the creation of new, or validation of existing, knowledge, is not a spectator sport and requires the active participation, or engagement, of the individual who is doing the learning.

1.3 Background and Related Work

This section provides an overview of some of the practices put into place during the lecture to promote engagement. The initial discussion relates to the non-technical approaches while the second discussion relates to the implementation of those approaches with the use of technology. The third section looks at innovations that have only become possible with newer technology and are not simply an electronic adaptation of a traditional approach. The benefit to these newly available innovations is greater student-to-student interaction; the availability of the current understanding of the lecture content of their peers while the lecture is taking place.

1.3.1 Traditional Approaches

Many approaches to encourage engagement by students in lectures have been implemented.

Allow Questions during the Lecture

Allowing questions during the lecture provides an opportunity for the lecturer to gauge the current level of understanding of the delivered content by the quality of the question. The response of other students to the question also provides insight into the groups overall level of understanding. Silence from the students while the question is asked and the answer provided is a good indicator that the content may not have been well understood. If the majority of the students cease paying attention while the question is being asked that would generally indicate that the question was not worth asking, the majority of the students have, or at least think they have, an understanding of the content. The capacity to allow questions during the lecture can be limited depending on the size of the venue and the number of students in attendance.

Red Card/Green Card

The student has a card that is red on one side and green on the other. Red means no or false while green means yes or true. The lecturer asks a question and the student answers; red (no) I did not understand the content just discussed or false that is not the correct answer. Green or yes, I think that information is correct or I think that answer is true. There are variations on this where there is also an orange, or yellow, card used to indicate that the student is unsure of the answer or that they have understood correctly the information provided.

Provide comprehensive notes prior to the lecture

Students are provided with comprehensive notes which they are expected to have read and understood prior to attending the lecture. This provides the opportunity for the students to have the lecturer confirm their new knowledge and expand on the concepts being presented.(Kiewra, 1985*b*)

Provide Partial (skeletal) Notes

These notes are provided prior to the lecture and have the students 'fill in the blanks' during the lecture. The idea being that the student is able to devote more time to watching and listening to the lecture if they are not devoting all their time to capturing the information in written form (Kiewra, 1985*b*). The requirement to fill in certain areas of the provided notes provides direction to the student on where the important content to be covered in the lecture is centred.

Peer Instruction

A short (ten minute) presentation focusing on a key point is delivered and then a qualitative test is administered. There is a period of discussion that follows the test where students explain their reasoning to a peer. Students are able to assess their level of learning and the lecturer is able to provide further instruction if the test scores of the group indicate further elaboration is required. This process is repeated multiple times throughout the lecture and accounts for approximately one-third to one-half of the lecture session. (Mazur, 1997; Crouch and Mazur, 2001)

Scheduled Breaks

During the lecture, breaks are scheduled to allow students to catch up on notes, ask questions of their peers, evaluate the information presented, or just have a quick respite from the process of capturing information.

Think-Pair-Share

Students think about the lecture material or a question that has been asked. After a defined time students are paired to discuss their thinking. The final stage is to share their thinking to a larger group, possibly the entire class (Lyman, 1987), (Silberman, 1996) cited in (Cheong, Bruno and Cheong, 2012).

Scheduled or Random Q and A Sessions during the Lecture

An activity that requires interaction from the students is either scheduled for a set time during the lecture where research indicates that attention starts to wander, or is delivered when the lecturer notices that attention is not as focused as it should be. The random delivery of this activity can also be applied when the lecturer wants to be certain that a particular concept has been understood by the class.

The Flipped Classroom

The flipped classroom has the student view pre-recorded lectures prior to attending the lecture. The lecture session itself consists of discussions and exercises to allow the students to gain a deeper understanding of the content.

Other Methods

Alternate teaching methods may include presenting the content from a different perspective. A short video or a guest lecturer explaining the importance of the content

provides the student with another source of information to aid in constructing their knowledge.

1.3.2 Electronic Interpretation of the Traditional Approaches

Certain of the traditional methods of encouraging engagement during lectures have been adapted to use technology.

Mobile Lecture Interaction

Mobile Lecture Interaction (MLI) allows students to anonymously ask questions of the lecturer during the session. The system also allows the student to vote for questions asked by other students. When a question collects a certain number of votes, or is seen to be very relevant the lecturer can answer the question or provide further information to allow the students to discover the answer themselves. (Costa, Ojala. and Korhonen., 2008)

Clickers

Alternate names are personal response systems, classroom response systems, student response systems, audience response systems, or class communication systems (Patry, 2009). A clicker is a technological adaptation of the traditional Red flag/Green flag, or simple show of hands, in response to a question posed by the lecturer. The lecturer poses a question to the class and the students return an answer using the clicker. The responses are automatically recorded on the lecturer's computer and presented in a visual format. The lecturer is then able to decide whether further elaboration on the content just tested on is required. They can be used to better engage students in lectures however, they do not inherently promote higher-order thinking skills ((Beekes, 2006) in (Cheong et al., 2012)).

Socrative

At its most basic *Socrative* is simply another clicker, an online quiz tool, however it has the benefit of not needing to purchase specific hardware, any web interface allows participation. In addition to simple yes/no answers the option to send out multiple choice and short answer quiz's is also possible. Students also have the option to leave an 'exit ticket' relating to how well they understood the content delivered, what they learned – in their own words, and the opportunity to leave a question for the lecturer. (Socrative, 2014)

E-notes

The idea behind *eNotes* (Wirth, 2003) is to provide accurate and complete notes to the students for use in the lecture. The provided notes will then support active learning by drawing the attention of the student away from rote writing and allowing them to focus more on the higher order cognitive skills of "perception, comprehension, and analysis of knowledge".

1.3.3 New Approaches available through Technology

The availability of new technology has provided further opportunities to increase engagement in the lecture environment.

Co-Scribe

CoScribe is a system that allows students to collaboratively annotate paper lecture slides using an electronic pen. Post lecture these slides are synchonised on a personal computer and are then able to be accessed via the CoScribe software viewer with the individuals annotations included as well as others who have taken part. While the interaction is not occurring in real-time the results of the interaction are available to the individual and this benefit is expected to assist with engagement in the class.(Steimle, Brdiczka and Muhlhauser, 2009*b*,*a*)

NoteBlogger

NoteBlogger is a Tablet PC application designed for blogging in the classroom and is derived from Classroom Presenter (Anderson, Anderson, Simon, Wolfman, VanDeGrift and Yasuhara, 2004). Attendance at the lecture sessions where this technology was implemented is part of the Ubiquitous Presenter digital classroom system at the University of Washington and students were already expected to bring laptops to the sessions in order to access viewing material or to participate in active learning exercises. The innovation that NoteBlogger provided was that it enabled the real-time viewing of the notes of another student. These notes were also available post-lecture.(Simon, Anderson, Hoyer and Su, 2004; Davis, Kelly, Malani, Griswold and Simon, 2007; Simon, Davis, Griswold, Kelly and Malani, 2008)

NotePals

Notepals (Davis, Landay, Chen, Huang, Lee, Li, Lin, Morrey III, Schleimer, Price and Schilit, 1999) makes the notes of an individual available to all other members of a group via a web interface and allows for the capture of content from all notes

relating to a specific context. Individuals notes are taken using a pen-based Personal Digital Assistant (PDA). These notes are uploaded to a shared repository and include metadata about the note such as the author, subject and a time/date stamp. The metadata allows viewers to select all content associated with their interest e.g., all notes from this mornings lecture, or all notes containing CSCW in the subject line. As with CoScribe, these notes are unavailable in real-time, but the opportunity to benefit from the collective nature of the information recorded is expected to encourage active participation is the session.

NoteTaker

Notetaker provided information regarding the ideal electronic device for taking notes and noted that it required a keyboard for the speed improvement over handwriting, a pen to enable faster and superior drawing than from a mouse while still needing the mouse for exact positioning of text and drawing within the page (Ward and Tatsukawa, 2003, n.d.).

Livenotes

Livenotes (Kam, Wang, Iles, Tse, Chiu, Glaser, Tarshish and Canny, 2005) enabled small groups of students to jointly annotate lecture slides in real time using Tablet PCs connected via wireless networks in a way that only required minimal institutional or pedagogical change and was independent of the size of the class in the lecture venue. The multi-user interface comprised of a shared whiteboard that did not support structured notes and did not allow a student to remove themselves from the distraction of others.

In summary, as previously discussed in this chapter there are a number of variables present in each lecture; the most important of which is the lecturer. The lecturer is in charge of the environment and is responsible for the pace and style of delivery of the content. The innovations presented above are all driven by the lecturer however not all lecturers can or will use them. For the occasions where the lecturer is not stimulating the engagement of the student, and the student is unable to engage in the lecture content, the remaining possibility to promote engagement is their fellow students. A student-centred approach is now possible due to the ready availability of suitable mobile devices that permit interaction. Innovative software for use on these devices can extend the reach of this interaction to multiple peers who may then assist in engaging the individual student in the lecture content, or increase the level of engagement that already exists.

1.4 Conclusion

The aim of the university is to produce graduates with certain attributes; one of which is the ability to learn (Järvelä, Näykki, Laru and Luokkanen, 2007). Multiple methods are used to provide information to students in a manner that engages them and allows them to develop knowledge however, the primary method of information delivery, the lecture, does not always provide the engagement required for students to attend, or remain engaged in the lecture. The fault can lie with the lecture content, the venue, the lecturer or the student themselves. It can be, and probably is, a combination of these factors. It is important that the individual student takes advantage of all possible access to formal sources of information in addition to their own independently sourced information. Learning is not a spectator sport and the individual must engage with the topic to develop their own knowledge. Failing to access, in a meaningful manner, the information provided by lectures means that potentially up to 50% of the formal contact time between the teaching staff and the individual student is lost.

Providing a solution that will improve the engagement of students in lectures will involve the application of practices and principles known to work in regard to educating university undergraduates. An understanding of the specific constraints that a lecture venue imposes with regard to creating a distraction must also be addressed, as will the features necessary in providing a solution that is educationally meaningful and accessible.

Chapter 2

A Student-Centred Solution to Engagement Underpinned by Peer-to-Peer Real-time Interaction

Any resolution to the problem of non-engagement by students in lectures must take into account the variables as discussed in Chapter 1. These include the content, lecturer, venue, and students.

The first section of this chapter identifies the constraints that will need to be addressed and discusses why they need to be factored into the solution. The second section presents the requirements needing to be met and why they are important in creating a solution that will promote educationally meaningful activity. The final section provides a summary of the core requirements applicable to a solution.

2.1 Constraints

As discussed in Chapter 1, the lecture is subject to many conditions that are not conducive to learning for all students; the lecture is regarded as sub-optimal in the literature with only a 5% learning retention rate (Costa et al., 2008). Differences in the venue and the lecturer impact on the individual student as does the content being delivered. One size does not fit all as far as a lecture is concerned; nor should it. A lecture provides the uniform delivery of information to an audience who are expected to capture that information and build knowledge from it. How they manage that process depends on the individual student.

The constraints relevant to the design of a solution include that interaction is driven by a student-to-student dynamic. It must be non-disruptive to the lecturer and to other

students in the vicinity, must be fast, and that any additional costs to the students for the use of the solution e.g., time, financial and cognitive, are considered acceptable by the student. A single solution able to be used for peer-to-peer interaction on all occasions, as well as providing for lecturer-to-student interaction as required, is the goal.

2.1.1 Peer Driven Interaction

There are two avenues to provide the engagement required for capturing information during a lecture session, the lecturer and the student. The solution is to be directed at the case where the lecturer is unable, or unwilling to provide this engagement and the student is unable to maintain engagement on their own. In many cases the student is not able to engage, or if they can initially engage, are unable to maintain that engagement for the entire session. It may be that they can only remain engaged for a certain time, drift off and then re-engage at a later point in the lecture, or it may be that they are engaged initially but when they lose focus they are unable to re-engage at all. If the lecturer is not providing sufficient stimulation to keep the students engaged, and the students own motivation and interest is not sufficient for them to remain continually engaged, the remaining option is to have the students engage each other. The solution will need to be peer driven, a student-to-student dynamic, however it will need to seamlessly accept interaction to and from the lecturer should the lecturer choose to provide input.

2.1.2 Not Disruptive to Others

The lecture venue is controlled by the lecturer. They control the content to be delivered, the style and pace of delivery, and the level of interaction permitted or encouraged. The solution must respect the conditions present, or likely to be present, in the lecture venue, such as the normative behaviour of no, or minimal, noise beyond the occasional whispering, and of minimal physical movement. The solution will need to ensure that it is not distracting to the lecturer or to other students attending the lecture.

Lecturer

The solution must not be disruptive to the lecturer; either through requiring a change in pedagogy, additional workload, or by causing increased noise or movement in the lecture venue.

Many lecturers are not convinced that they need to be more interactive in their lectures, or that there is a capacity to do so, depending on the numbers of students attending the lecture. The interaction dynamic in a lecture with 20 students is different

to that with 200 students. A change in pedagogy is not something that can be dictated to the lecturer by the students. Lecturers who do not see the reason behind more interaction during the lecture are not likely to change their material to facilitate that interaction.

In addition to not requiring a change in pedagogy from the lecturer the solution must not require additional workload. There should not be a requirement for additional input from the lecturer beyond their normal practice, although should the lecturer choose to embrace the use of the solution then it should be able to accommodate interaction between the lecturer and the student. This interaction may entail minimal input such as providing the lecture slides in an electronic format prior to the lecture, or it may extend through to a fully interactive dialogue occurring throughout the lecture including pushing out additional information such as worked examples from questions asked during the lecture.

The solution must not cause additional noise or movement. Increased noise in the venue will not be tolerated if it is seen to be impacting on the ability of students in the lecture to learn e.g., dictating into a voice recorder instead of transcribing onto paper or an electronic device. The increased movement or sharing of artefacts e.g., passing of physical objects such as notepads may also cause disruption to the lecturer as well as other students in the vicinity. Some lecturers even ban the use of Laptops outright or require that they are only to be used when situated at the last row of the lecture room (Sana, Weston and Cepeda, 2013) due to the distraction that the screens provide. Screens viewable to others in the room, such as those students situated behind other students using laptops, is a distraction with the temptation to see what is happening on the screen generally too much and which results in the attention of the student being diverted from the content being delivered. Sana (Sana et al., 2013) identifies that students who were in direct view of a student multitasking on their laptop during a lecture scored lower on a test compared to those who had no such distraction in the form of a laptop screen in their viewing area.

Students

In addition to not being disruptive to the lecturer the solution must not be disruptive to the students in the vicinity. Students have been known to make their opinion heard to other students who are causing a disruption and affecting their ability to engage with the content being delivered. Of necessity, the solution will provide a distraction to the student through its use so the potential gain in using the solution must be seen by that student to outweigh the distraction. The solution should minimise the availability of distraction available to students who consider they are able to multitask by watching YouTube or listening to music using services such as Spotify, Pandora, Apple Music etc. at the same time as taking notes on the lecture content. The solution

should also minimise the distractions forced upon students by notification updates from programs such as Facebook, email etc. where their attention is intentionally drawn away from the task at hand by applications running on their mobile device. "We found that participants who multitasked on a laptop during a lecture scored lower on a test compared to those who did not multitask, and participants who were in direct view of a multitasking peer scored lower on a test compared to those who were not (Sana et al., 2013).

The solution will need to integrate into the conditions present in a lecture including where the lecturer has an interactive style and wishes to make use of available technology during the lecture. For the solution to have a realistic chance of success it must be a single application that is in use by a student. If a student has to use multiple technology applications, depending on the involvement of the lecturer, the likelihood of them devoting the time and effort to become proficient in their use will be diminished over just having to master a single application.

2.1.3 Fast Text Entry

The solution must be on a par with traditional methods such as pen and paper for note-taking. The traditional method of taking notes using pen and paper works out to about 31 words per minute from the spoken word output of between 110 - 150 words per minute and the solution will need to provide text entry of at least this speed. The use of continuous entry text methods such as Swype (Nuance Communications, 2010), SwiftKey (TouchType Limited, 2008) and Google Keyboard (Google, 2015) allows for users whose keyboard entry method is described as 'hunt and peck' to significantly increase their speed of text entry.

2.1.4 No Additional Costs

While the definition of what is an acceptable cost will vary for each individual the solution should enable the greatest possible uptake to occur. Providing the solution for the widest range of mobile devices at no cost to the student will enable uptake regardless of the current economic capacity of the student.

The Technology Acceptance Model (TAM) (Davis, 1989) initially, and the later Unified Theory of Acceptance and Use of Technology (UTAUT) (Venkatesh, Morris, Davis and Davis, 2003) is used to predict the uptake of a technology and identifies that there needs to be a Perceived Usefulness (PU) to the solution as well as a Perceived Ease of Use (PEU) by the user of the technology. If the user does not see that the use of the technology will make a positive difference to their output, from a price they are willing to pay (time, financial, effort), then there will be a reluctance to use the technology. If the user considers that the costs to themselves in using the technology is outweighed by the benefit of using it, they will embrace the system.

The solution must not require additional costs, either financial, time or cognitive, beyond that which the student finds acceptable.

The following example illustrates this point. I need a program to remove the 'red eye' from my digital photographs. Currently I use the Paint program in Windows to do this and it takes a few minutes per photograph to accomplish the task. I am able to acquire for my computer, for a small fee of $5.00, a program called Red-Eye Away that will allow me to remove the 'red-eye' in less than a minute and it will only take me about 10 minutes to familiarise myself with how to use the tool effectively. An alternative is that I can acquire a free plug-in for Adobe® Photoshop that will do the same thing in seconds. Unfortunately I need to spend many hundreds of dollars to purchase Adobe® Photoshop and then spend 20-30 hours to understand the basics and then a few hundred hours more to get really comfortable using the software. I might even have to buy a new computer powerful enough to run the software.

I can continue with using Paint but I am also happy to spend the small amount of money and time becoming competent in using Red Eye Away however I am not going to be purchasing Adobe® Photoshop for this purpose as I consider that the financial, time and cognitive requirements do not provide an adequate return for the investment.

Financial

The student should not be required to purchase additional hardware or software specifically to access the solution, nor pay ongoing fees for its use. There is resistance from students to purchasing hardware such as 'clickers', even when used appropriately, as they are often seen as nothing more than glorified attendance registers. Enforcing the purchase of a specific device will not agree with everyone. "I already have a laptop; why do I need to buy a tablet?", "I already have an iPad; why do I need to buy an Android tablet?", "I already have an iPad and a home computer; why do I need to buy a laptop?"

The solution should not require the purchase of additional software to enable it to function. The solution should be standalone i.e., not be a plug-in to another piece of software unless that software would be expected to already exist on the individuals mobile device.

There should not be any ongoing costs to using the solution. "Why do I have to use up my free SMS's just to answer a question or vote for an answer?", "Why do I have to pay for this program using my mobile data from my phone plan?"

The financial costs to acquiring the solution should not be deemed excessive by the student nor should any ongoing costs, if applicable.

Time

The pace of the lecture is beyond the control of the student so the solution cannot slow down the capture of the information.

The traditional method of capturing notes is to use pen and paper. Methods such as typing and annotating either partial or full slides of the lecture notes provided, are other alternatives. The solution must not be slower than that afforded to the individual using the most common method of pen and paper.

The time required to learn how to use the solution efficiently and effectively should not be onerous. The individual should be able to spend a few minutes with the solution to get the gist of how it works and with minimal practice be competent. Greater efficiency arrives with increased use.

Use of the solution cannot require more time than traditional methods. Opening a notepad, grabbing a pen and commencing to write is a task that has most likely been performed thousands of times by the individual student.

A solution that required a warm up exercise, or calibration of a device prior to each use would not be acceptable.

Cognitive

The solution must not require a cognitive load greater than that which currently exists to replicate their current information capturing activity during a lecture. If circumstances dictate that there is no other student to cooperate/collaborate with during the occasional lecture then the solution should not be less efficient than using pen and paper. Beyond this load the additional effort required to share information in real-time needs to be seen as beneficial and therefore worth the additional cognitive load.

The cost of using the solution must be acceptable to the student.The question they will ask is "Does the personal cost involved in adopting this solution outweigh the expected benefit?" If the answer is yes, the solution will not be adopted.

In addition to overcoming the constraints identified, the solution must address specific requirements to ensure it is fit for the purpose of facilitating educationally meaningful activity in the lecture environment.

2.2 Requirements of the solution

The primary requirement of a solution is that it provides the opportunity for the students to interact with others during the lecture, and gain a benefit from that interaction, while at the same time doing so in a manner that does not distract the lecturer or other

students in the lecture venue. The interaction will cause some level of distraction as attention is removed from the lecturer for a period of time, this distraction must be considered by the student to be worth it through the gain in information captured and knowledge gained by cooperating and/or collaborating with others. The solution must also promote practices that are known to be beneficial to undergraduate education, the interaction must be educationally meaningful.

2.2.1 Real-time interaction

The solution must allow students to interact quickly and silently in real-time with selected peers to share information and knowledge. The interaction will need to be text based as audible conversation will be too disruptive. The solution must not require the intervention of the lecturer beyond their normal duties.

Permitting Interaction

Short of an outright ban on mobile devices in the lecture room the solution should be available for use.

Encouraging Interaction

A requirement of the solution is that it encourages the student to use it. As previously discussed, this means that there needs to be a perceived usefulness (PU) to the solution as well as a perceived ease of use (PEU). If the user can see that the use of the technology will make a positive difference to their output from a price they are willing to pay (time, financial and cognitive effort) then there will be an embracing of the technology. The solution needs to be implemented on the types of mobile devices that are in use by the students and be accessed in a familiar manner. A menu based structure more familiar to a Unix/DOS based system will not be as readily accepted as a system using icons familiar to the current generation of students using the touch screen interfaces of Apple, Windows and Android based systems.

2.2.2 Interaction must be Educationally Meaningful

What is meant by educationally meaningful activity?

In general this does not include the use of Facebook, Twitter etc., although it is interaction and has been/is being used by some lecturers. The taking, making, and sharing of notes are all recognised as being of benefit to the individual in their accumulation of knowledge.

As discussed in Chapter 1; note-taking is not the only measure of engagement in the lecture but it is the tool we are using to increase that engagement.

Note Taking

Note taking is undertaken to fulfil two major functions; to record information and/or to aid reflection and, beyond a simple task such as writing up a shopping list or writing in a diary, its purpose is to capture transmitted information in such a way that nothing presented will be forgotten. (Boch and Piolat, 2005)

Note taking is believed to help students focus and pay attention and retain information (Dunkel, 1988). In addition, the taking of notes is proven to be an effective learning technique that aids memory of the lecture by fostering encoding, articulation and rehearsal (Bligh, 2000).

Some memorisation is occurring while note taking is taking place, especially when the note taker fully understands the original content of the notes (Williams and Eggert, 2002).

There are several different note taking strategies and a requirement of the solution is that it provides for the student to take notes in the fashion they are already comfortable and familiar with. This means the capacity for traditional notes transcribed in a linear manner, the Cornell Method, mind-maps, diagrams, colours etc.

In the context of a university lecture environment note taking is generally seen as a passive process where the content is detailed in the order it is presented, but which may not be the most logical for the students own level of knowledge, this must then be reviewed and re-written to organise it to their own liking; the process known as note making.

Note Making

Student note taking is important to the learning process as described above. It is the foundation for the process of note-making, the active process of constructing a meaningful representation of the content you found relevant in a lecture.

Note making is the reviewing of the notes taken during the lecture and re-writing them in a more organised fashion that reflects the level of knowledge gained. If students are doing the pre-reading and other assigned exercises then they should be able to adequately organise the content being delivered to them, they are therefore making notes during the lecture, instead of just taking them. This does, of course, depend on the cognitive and information processing capabilities of the individual student.

Higher academic achievement has been shown in students who review their notes than in those who do not. (Hartley and Davies, 1978; Kiewra, 1985*a*; Kobayashi, 2006).

Students that enter a classroom with previously reviewed notes, their own or lecturer provided, tend to have better recall since there is less stress involved with listening and interpreting information accurately (Kiewra, 1985*a*).

Kiewra determined that the review and reorganization of notes led to higher test achievement (Kiewra, 1983), while higher academic achievement has been shown in students who review their notes than in those who do not (Hartley and Davies, 1978; Kiewra, 1985*a*; Kobayashi, 2006).

Note Sharing

Sharing notes with at least one other person involves discussion of those notes and means that alternative opinions on the content meaning are explored and either agreed with or amended as required. Either way, it is a further entrenching, or codifying, of the knowledge so that it can be accessed and used as required.

2.2.3 Interaction should promote Good Practice

In 1987 Chickering and Gamson delivered the *Seven Principles for Good Practice in Undergraduate Education* (Chickering and Gamson, 1991). These principles were not intended as a silver bullet, they were guidelines based on 50 years of research identifying how students work with one another, how teachers teach and their students learn, and the way that students and teachers talk to each other. Implementing these principles is primarily the responsibility of the teachers and the students however it is also the responsibility of the university to enable the conditions which allow the environment to exist and therefore promote these principles.

These principles are as follows:

P$_1$ Encourages contact between students and faculty
"Frequent student faculty contact in and out of classes is the most important factor in student motivation and involvement. Faculty concern helps students get through rough times and keep on working. Knowing a few faculty members well enhances students' intellectual commitment and encourages them to think about their own values and future plans."

P$_2$ Develops reciprocity and cooperation among students
"Learning is enhanced when it is more like a team effort than a solo race. Good learning, like good work, is collaborative and social, not competitive and isolated. Working with others often increases involvement in learning. Sharing one's own ideas and responding to others' reactions improves thinking and deepens understanding."

P$_3$ Uses active learning techniques
"Learning is not a spectator sport. Students do not learn much just sitting in classes listening to teachers, memorizing prepackaged assignments, and spitting out answers. They must talk about what they are learning, write about it, relate

it to past experiences, and apply it to their daily lives. They must make what they learn part of themselves."

P$_4$ Gives prompt feedback
"Knowing what you know and don't know focuses learning. Students need appropriate feedback on performance to benefit from courses. In getting started, students need help in assessing existing knowledge and competence. In classes, students need frequent opportunities to perform and receive suggestions for improvement. At various points during college, and at the end, students need chances to reflect on what they have learned, what they still need to know, and how to assess themselves."

P$_5$ Emphasizes time on task
"Time plus energy equals learning. There is no substitute for time on task. Learning to use one's time well is critical for students and professionals alike. Students need help in learning effective time management. Allocating realistic amounts of time means effective learning for students and effective teaching for faculty. How an institution defines time expectations for students, faculty, administrators, and other professional staff can establish the basis for high performance for all."

P$_6$ Communicates high expectations
"Expect more and you will get it. High Expectations are important for everyone – for the poorly prepared, for those unwilling to exert themselves, and for the bright and well motivated. Expecting students to perform well becomes a self-fulfilling prophecy when teachers and institutions hold high expectations of themselves and make extra efforts."

P$_7$ Respects diverse talents and ways of learning
"There are many roads to learning. People bring different talents and styles of learning to college. Brilliant students in the seminar room may be all thumbs in the lab or art studio. Students rich in hands-on experience may not do so well with theory. Students need the opportunity to show their talents and learn in ways that work for them. Then they can be pushed to learning in new ways that do not come so easily."

Lectures can account for approximately 50% of formal staff-to-student contact time. It makes sense to maximise the use of that time and if the students are not able to maintain their engagement from the efforts of the lecturer or from their own interest and motivation the only avenue remaining for engagement is that of their peers. The principles for good practice in undergraduate education remain relevant to this day and should be promoted at every opportunity. There is no reason that these principles cannot be implemented, excepting Principle 1, from a student to student perspective wherever possible. These principles are explored in greater depth in the next chapter where my solution to the problem is presented.

These principles remain relevant to this day and any potential solution must address the implementation of these principles as a core requirement.

2.3 Conclusion

The constraints the solution has to contend with is that it provides silent, peer-to-peer interaction using electronic devices.

- Silent, because oral communication is too distracting to others in the venue.
- Peer-to-peer interaction, because it is the only avenue available to the student when they fail to maintain sufficient engagement with the topic content by themselves, and are not receiving the necessary stimulation from the lecturer.
- Electronic devices, because interaction in the form of shared real-time physical artefacts, such as notes on paper, to someone who is not co-located is not practical, nor possible for sharing among a group of more than two or three. The electronic devices need to be the type of mobile device that the student either already owns, or aspires to own, such as Smartphones, Phablets or Tablets. This allows for the greatest possible uptake as there is no requirement to purchase or hire another device and learn to use it. The acceptance of the mobile device as being useful, and easy to use, in other aspects of the students daily activities means that there is a minimal cost; time, financial, and cognitive effort, to the student in using the solution.

The requirement of the solution is that it provides real-time interaction and both encourages and promotes principles and practices that are known to be beneficial to the students in the construction of their knowledge.

The next chapter provides details of the implementation of a solution; *GroupNotes*, and discusses how it meets the constraints and requirements identified in the current chapter, as well as introducing the psychology behind the design decisions.

Chapter 3

GroupNotes: Facilitating Student-Centred Real-time Note-taking Using Mobile Devices

GroupNotes is designed to allow the widest possible uptake of the solution by implementing it on mobile devices known to be in use by the student population and is designed to allow for the most diverse range of students to form a group, regardless of cognitive ability. A group is able to be formed using whatever criteria the group members choose. A group may consist of a student who averages a Pass grade, another at Credit level, the third at Distinction level and the final member at High Distinction level who all choose to work together for reasons of their own; they share a common heritage, have worked together before, play in the same football team or already have an existing friendship.

The next section discusses the related work most responsible for developing this solution. The following sections outline the manner in which *GroupNotes* meets the specific constraints and requirements as identified in Chapter 2 and discusses, where applicable, the psychology behind the decisions made in its design.

3.1 Inspiration

The work of *Notetaker* (Ward and Tatsukawa, 2003, n.d.) (see page 19) suggested that the ideal electronic device for taking notes required a keyboard for the speed improvement over handwriting, a pen to enable faster and superior drawing than from a mouse while still needing the mouse for exact positioning of text and drawing within the page.

While larger devices such as a Tablet PC may provide a more usable learning environment (Simon et al., 2008; Kam et al., 2005), not all students are able or willing to purchase such a device, bring it to university with them, and then actually use it in the lecture environment. Voluntary self-ownership and familiarity with their own device are a key to removing the major learning curves associated with new technology. With the current generation of Smartphones, Phablets, and Tablets there will be no additional learning or monetary costs to students in using these using already-owned mobile devices in the lecture environments (Litchfield, Raban, Dyson, Leigh and Tyler, 2009). The touchscreen interface, possibly with a stylus, allows for exact positioning and ease of drawing and text entry. Combined with the technical sophistication in computation power, screen size, storage, easy-to-use interface, portability, and wireless connectivity, they remove the major obstacles to providing students viable technical solutions to their learning needs as evidenced with the recent introduction of *Hotseat* (Aagard, Bowen and Olesova, 2010) and *MLI* (Järvelä et al., 2007).

An important inspiration for our research was *Livenotes* (Kam et al., 2005) (see page 19), which enabled small groups of students to jointly annotate lecture slides in real time using Tablet PCs connected via wireless networks in a way that only required minimal institutional or pedagogical change and was independent of the size of the class in the lecture venue. However, its multi-user interface was a shared whiteboard that did not support structured notes. The single-document interface did not allow the individual student to concentrate solely on their own task, or flexibly choose their preferred manner of working with their peers. *Livenotes* provided a single commonly shared workspace where all content was visible and editable to all group members.

GroupNotes is a client-server application that enables real-time, silent, peer-to-peer interaction on currently available mobile devices through an innovative interface. *GroupNotes* is a multi-user, multi-document, multi-interface application that permits an individual student to share the content they generate, notes, drawings, diagrams, questions etc., with selected other students in a group. This content is shared in real-time with all other users in the group with each individual able to limit the quantity of information in view at any time to meet their own requirements. The manner in which a group member chooses to view the available information sources does not impact the ability of any other student to view the information differently. *GroupNotes* provides multiple shareable individual workspaces that can be flexibly viewed and edited by all group members without adversely impacting other group members.

3.2 Meeting the Constraints

In addition to meeting the provision of peer-to-peer driven, real-time, silent interaction on electronic devices GroupNotes meets and extends the stated constraints of a solution by allowing for a student to provide input to a group without negatively impacting on

their own learning. A shared virtual workspace is currently available using applications such as Google Docs (Google, 2014) or Codoxware (Codoxware Pte Ltd, 2014) however there is no capacity for a student to reduce the distraction caused by others working within the same document. *GroupNotes* provides a unique interface that allows the user to contribute while at the same time not causing themselves more distraction than they are comfortable in dealing with.

3.2.1 Peer Driven Interaction

The interaction is peer driven in that it is not reliant on the lecturer. Students are, in general, wanting to learn however they are not always able to remain engaged in the lecture environment even with the best intentions of the lecturer and themselves. This solution involves the members of the group bringing their intention to engage in the lecture into the group environment and then having the group dynamics maintain that intention to engage.

3.2.2 Self-selection of Group

The students who do choose to access *GroupNotes* are required to self-select their own groups. The lecture is not an environment where formal groups are created by the lecturer. Students may choose to work together to try to ensure complete coverage of the material presented and share those notes after class however this is not a formally assigned practice; it is up to individual students to find others to work with if they choose. Students are not required to use *GroupNotes*; it is an entirely voluntary decision to work with others and therefore the 'social loafing' aspect common to many formal student groupwork tasks within the university can be eliminated. If a group member is not meeting their commitments then they can be excluded from the group and replaced, if necessary, with someone who will.

Motivation to Join

The motivation behind an individual voluntarily joining a specific group may be either intrinsic or extrinsic. Intrinsic in the case where the group member chooses to assist their fellow group members because it is personally rewarding to do so. Extrinsic in the expectation of an external reward, i.e. assisting their fellow group members to achieve more, or to help themselves to achieve more (Bock, Zmud, Kim and Lee, 2005). The particular motivation of the student to join a group is not important, the fact they have voluntarily joined together to work towards a shared goal is what counts.

Benefits to Joining

The primary benefit to joining a group and using *GroupNotes* is the expected gain in the capture of information, from the lecturer and other group members, to increase the learning of each individual involved. A further benefit toward membership in a self-selecting group, beyond any immediate personal gain, is that it includes an improved relationship with others and a greater likelihood of reciprocal behaviours from the members in the group for other activities (Constant, Kiesler and Sproull, 1994).

There are also social advantages to being part of a group. A sense of belonging and of purpose, a validation that your knowledge and experiences are valued and a reduction in loneliness are all important parts of the emotional well being of the individual. A university can be a lonely place particularly if you are away from your established support group of family and friends. Anonymity is both a blessing and a curse for the individual in the lecture room. As part of the 'anonymous mass' there is only a small chance that you will be singled out in a lecture room containing 300 students and expected to answer a question, and perhaps leave yourself open to some form of derision from your peers however there is also little opportunity for the individual to feel connected. They are simply one individual in a class of individuals who are present in an environment that generally does not reflect the manner in which they live or learn. As part of a small group the pressures within a lecture are reduced, while it may be that the culture, upbringing or shyness (lack of confidence) of the individual prevents them asking or answering questions of the lecturer, particularly in front of a large audience, there will not be the same reticence to display their potential lack of knowledge within the safe confines of the group where their input is valued.

3.2.3 Not Disruptive to Others

GroupNotes is designed to function without any input from the lecturer but has the capacity to include input from the lecturer if they choose to use the application. In addition to not providing distraction to the lecturer or to other students in the vicinity of those using *GroupNotes* the design of the interface allows for individuals within the group to control the level of distraction they are subjected to from others within the group.

Lecturer

GroupNotes does not require that the lecturer change their pedagogy or require further work from them. The *GroupNotes* server is enabled and individuals form groups with others of their own choosing. The lecturer is unaware how many students are using *GroupNotes* and in how many groups they have formed unless they choose to find out. The interaction is solely driven by the students.

GroupNotes is enabled on mobile devices such as Tablets and Smartphones but will also be available on laptops and PC's. The expectation is that the Tablet is going to be more ubiquitous in the future although not quite to the levels of the Smartphone. The Tablet has many advantages in the university environment; from light weight and generous battery life to excellent storage and connectivity options coupled with a screen size adequate for generating content. Content creation as well as content consumption is possible. The angle of the screen on a Tablet when in use is different to that of a laptop; it is much closer to parallel and therefore less likely to divert the attention of other students in the vicinity as they will be unable to view the screen. If they are unable to view the content on the screen then it is not a distraction to their learning and therefore is unlikely to be a problem to the lecturer in terms of it distracting others from their learning. While *GroupNotes* on a laptop will still have the same distracting capabilities in terms of the screen being visible the fact that it will be accessing a dedicated server that does not permit access to the internet will reduce the opportunities for the student to multitask by having programs such as Facebook, Instagram, Twitter etc., in use while they are taking notes. The capacity for distraction by the screen containing content other than *GroupNotes* being in view, is much reduced because the students will be aware that nothing interesting is happening that they can learn from that screen. The noise from multiple keyboards in use is also reduced by the use of Tablets, Phablets and Smartphones which generally use the onscreen (silent) keyboard.

Students

GroupNotes runs on a dedicated server which does not provide access to outside programs. Once a group member has accessed the *GroupNotes* system and joined with their group members their connection to the application is visible to all those members. The only way a group member could access a distracting application such as their own email, Twitter, Facebook, YouTube etc., would be to disconnect from the *GroupNotes* server and access another server. This exit from *GroupNotes* would then be immediately obvious to the other members of the group. This feature encourages Principle 5 – time on task.

The manner of holding a Tablet means that the screen is not always available for viewing by anyone other than the person using it. This means that the distraction caused by the screens of laptops is not as large a distraction, the angle of operation of a Tablet screen is more likely to be 30 degrees from parallel with the desk surface compared to 60-70 degrees from a laptop. The opportunity for the screen to distract other students in the vicinity is much reduced with a Tablet.

In the same manner that increased use of mobile devices such as Tablets, Phablets and Smartphones will reduce the impact of screens being visible to others in the vicinity

it will also reduce the noise of keyboards in operation. While some Tablets will use an external hardware-based keyboard many will use the onscreen (soft) keyboard as will the vast majority of Phablet and Smartphone users.

Students within the Same Group

GroupNotes provides for the capacity to exclude distraction from within the group itself through the design of the interface.

GroupNotes provides all generated content to all users within the group in real-time but allows each user to determine how and when they will access that content. The only exception to this capacity to remove distraction is that there is no function available at present to exclude a group member from writing in another members workspace. *GroupNotes* allows any group member to generate content in any other members workspace therefore group rules will need to be established, and respected. If a group member cannot manage viewing others work in real time, or the distraction caused by others generating content into their own workspace, but has joined the group to allow others access to their content in real-time, then the other group member's need to respect that request. The option of a group member leaving the group due to their wishes not being respected is always available; group membership is voluntary after all.

3.2.4 Fast Text Entry

There is no shortage of innovative and very quick to learn text entry methods available for mobile devices such as the continuous entry SwiftKey (TouchType Limited, 2008) and Google Keyboard (Google, 2015) amongst other available for Android and Swype (Nuance Communications, 2010) available for both Android and Apple. Handwriting applications such as Squid (Innovation, 2015) for Android and Windows devices, INKredible (INKredible, 2015) for Android and Apple devices, and Penultimate (Evernote Corporation, 2015) and Notability (Ginger, 2015) for Apple these applications are improving their usefulness all the time. A new application, WriteIt (Lenovo, 2015) from Lenovo removes the handwriting experience from being tied to a specific application; it is able to be used in any text field. The ability to customise dictionary entry will also increase the speed of entry. A custom glossary of terms required for a specific discipline could be uploaded to the device for optimised predictive text; Latin terms for plants in a Biology class would not be interpreted as something else. There could also be a discipline specific shorthand notation installed. If you are in the Computer Supported Cooperative Work (CSCW) field and select that dictionary then when entering 'OT' the system would would automatically insert operational transformation while a physiotherapy student, after selecting their Physiotherapy glossary, would have occupational therapy inserted.

3.2.5 No Additional Costs

GroupNotes is designed to operate on the personal mobile devices that students already own, or aspire to own, such as a Smartphone, Phablet or Tablet. These personal mobile devices are the appropriate platform for a solution as it means no, or minimal, additional costs, either financial, effort or cognitive, to use the solution.

The personal mobile device is the appropriate device to build a solution on as there is no financial imposition on the student to purchase an additional device, or in learning to use it, as they have already learned how to use the device voluntarily for their own purposes. The application is designed in such a way that it follows standard conventions for touch screen operation such as dragging, swiping left or right, pinch to zoom etc. meaning there is no requirement for the student to spend more than minimal time and effort in understanding how to use the solution. There will be no additional monetary costs to use the device in the lecture environment as wireless access is already provided free therefore removing a major concern of students (Litchfield et al., 2009).

Financial

The personal mobile device is the appropriate device to build a solution on as there is no financial imposition on the student to purchase an additional device specifically to use the solution. Unlike solutions such as MeTL (Bailey, Hagan, Hagan, Franke and Sanson, 2011) at Monash University that require a Tablet PC, *GroupNotes* operates on the mobile device that the student is likely to have with them in the lecture room for use in other aspects of their daily life. The technology acceptance model (TAM - discussed in Chapter 2) has already identified that the students are already convinced of the worth of their mobile devices and have already acquired them. These mobile devices are able to connect to free wireless networks provided within the university meaning there is no ongoing charge to use the solution. It is expected that the use of the software by students would be free. Retention of current students is a major concern of University administration and a solution that enables those students to have a sense of being able to achieve, and therefore remain enrolled in their course, will be welcome by the university administration.

Time

The student is already competent in the use of the device for purposes of their own use such as using Facebook, Instagram etc. They know how to use the keyboard of their choice, whether traditional or an updated method such as Swype (Nuance Communications, 2010). All that remains in to convince them that *GroupNotes* is beneficial to them in the lecture environment in terms of its Perceived Usefulness (PU) and Perceived Ease of Use (PEU) and a minimal amount of time and effort to understand the

basics of its use. During our testing even those who did not already have a Smartphone or Tablet were able to understand how *GroupNotes* worked, how to alter the interface to suit themselves, and how to use the continuous entry keyboard (Google Keyboard on a Nexus 7 device) within the ten minutes allocated for training. This is not a solution that requires extended practice to become comfortable with navigating, nor to achieve the speed of content entry required, either text or drawing.

Cognitive

The touchscreen interface provides for an intuitive method of interaction and a consistent application of methods to control the device such as swiping up or down to scroll through a screen, pinching to zoom the content in greater or lesser detail, double-tap to highlight a word etc. *GroupNotes* applies the same style to its design such as swiping up or down to scroll through a document or the dragging of a workspace into an active area where written interaction is possible or to a passive area where the content is viewable only.

During testing those who had prior experience with a touchscreen device had no problems operating *GroupNotes* and manipulating the interface to suit their own needs, including during the formal testing. The few testers who had no prior experience with a touchscreen were also able to operate *GroupNotes* satisfactorily within the ten minutes provided for familiarisation, including acceptable speed with the continuous test entry keyboard. During a small test the quantity of notes taken using pen and paper was similar to that obtained using Swype on a Tablet meaning the speed of text entry, even for novices, was at least comparable with traditional methods.

GroupNotes does not rely on real-time interaction. It is available when and where group members choose to use it to their advantage and are accepting of the higher cognitive load it will require. The capacity of the student to accept and deal with the additional cognitive load will vary from student to student; from those who are able to maintain all available generated content being in view at all times, to others who will only access the content of others in real-time when they are struggling at a certain point of the lecture and without some added perspective from another are in danger of switching off their attention. Others may simply be unable to deal with information provided by other than the lecturer and never view the content generated by others in their group in real-time. All points of this spectrum are catered for as the individual is able to alter the size of the screens visible, and therefore the amount of information in view at any given moment.

The design of *GroupNotes* is directed to ensuring that there should be no negative impact from its use. If a group chooses to only ever view the content generated by the other group members post-lecture, but remains engaged in order that they meet the agreed commitment to the shared goal, then *GroupNotes* is meeting its objective of

attracting and maintaining students engagement in the lecture content. If a student is having an off day and cannot cope with multiple information sources they are able to arrange their interface to only display their own content. The interface is not fixed; it is purposely designed to allow for manipulating at any time the individual requires.

3.3 Meeting the Requirements

3.3.1 Real-time interaction is required

GroupNotes provides the availability for real-time interaction at the time and choosing of each group member and this flexibility also provides the encouragement for its use. The group member can contribute to a shared goal without negatively impacting their own personal goal. The interaction is strengthened by making all generated content uniquely identifiable to a specific group member; this allows the individual to weigh the relative strengths and weaknesses of that content at the point of confirming their own, or creating new, knowledge.

Permitting Interaction

Interaction is permitted because a platform for interaction is available to the students; *GroupNotes* is designed to use this platform of mobile devices in such a way as to minimise the possibility of distraction to either the lecturer or to other students in the vicinity. If their is no distraction to the lecturer and the lecturer does not determine that *GroupNotes* is causing a distraction to other students who are trying to learn there appears to be no valid reason for it not to be permitted.

Encouraging Interaction

If the potential for a more complete capture of the information being delivered is available I believe the opportunity will be grasped regardless of when the information is processed by the individual. Interaction is available through written communication and the inclusion of a unique multi-user, multi-document interface allows for the interaction to be viewed as and when the user requires. All content in real-time, none in real-time unless specifically needed at a certain point of the lecture, or none in real-time at all with all viewing of the multiple information sources delayed until post lecture. The capacity of the solution to allow for individuals to set their interface to regulate the amount of information provided in real-time without impacting on the flow of information to any other user will encourage the uptake of the solution. The ability to cooperate, collaborate or a mix of the two during the lecture will encourage participation. Depending on the skill, ability and preferred work style of the individual in

the group and the manner in which they choose to go about capturing the information being delivered will determine the working arrangements. In a group of four it may be that all group members take their own notes with the result being four sets of notes available for the members to review. It may be that the group of four allocates specific roles to the group members; pairs may be formed where one member performs the higher cognitive function of listening to the lecturer and generating the notes. the second member of the pair is responsible for ensuring that the notes generated accurately reflect the information they received. They may make only a few alterations or additions to the first members notes. At the end of the session there are potentially two sets of comprehensive notes instead of four partial sets. The ability to work with people they choose, for a shared goal of greater information capture and sharing to promote greater knowledge by using the available time in a lecture to its best advantage should be encouragement enough. Interaction is encouraged by the ability to provide a result greater than that which was possible alone; something not generally possible with the traditional nature of note-taking in isolation. This is not universal; there are always individuals who are able to capture the information provided during the lecture and attain the required standard of knowledge through their own resources. The uptake of *GroupNotes* is expected to be those individuals who do not have that capacity however there will still be these high performing individuals who participate from their own motivations. The natural state of learning for an individual is in a social context. Knowledge is constructed with through interaction with others in the community such as teachers and peers and the opportunity to continue this learning paradigm in the lecture context is expected to be attractive to most students, particularly if this additional input is able to be accessed without causing distraction beyond what they feel comfortable in dealing with.

Identifying Interaction

Interaction is uniformly identified in this multiple workspace design. Each user has their own workspace, identified by a picture/avatar of the group member and a unique colour for the workspace ID panel and the text or drawing that is produced. This workspace can be written in by other members of the group and will show up in the unique colour of the member doing the writing, not the colour of the owner of the workspace. There is also a shared workspace that does not belong to any particular user but belongs to all members where identification is by colour of the contributed text/drawing alone. In addition to writing there is also the capacity to draw in any of the workspaces, your own, someone else's or the shared space. Emphasis on text is available through boldfacing, underlining and italicising of the selected text.

The identification of the group member responsible for any content generated is important to group members for their ability to assess the weight they give to that content. If a member of the group is known to be particularly strong in an area and

their current note or comment is different to that of other group members it may still be the information that is accepted by the group member needing that information in real-time to understand the current content being delivered.

3.3.2 Interaction must be Educationally Meaningful

The interaction is via text and is concerned with the formal note-taking process during the lecture; this also provides the vehicle for the making and sharing of the type of content, informal note, that is currently shared by the whispering or passing of a physical note to a co-located student. Simply being aware that all notes are to be viewed by others will alter their composition and will encourage them to remain relevant to the lecture content. The notes may be more complete and with greater structure when they are going to be viewed by another person due to their own motivation to do a good job; do all the pre-assigned reading of texts, reviewing and sharing of the previous lectures notes etc. This process of note-taking during the lecture may evolve into note making through being more structured and from better preparation. Not all individuals will be able to make notes at the initial lecture and will need to review and rewrite, or make, notes. The fact that the notes are immediately available to the other members of the group and also at a later date means that the notes are being shared by default.

The process of taking, making and sharing of notes is known to be beneficial to the learning outcomes of the individual. *GroupNotes* allows a group to create multiple perspectives of the content provided during a lecture with the full knowledge it is available to the other members whenever they choose to access it. This knowledge will influence the quality of the notes generated as they will be written with that in mind by providing additional information to assist the other users with their own comprehension of the notes.

Note Taking

Note taking by students is an expected part of the lecture experience from both the point of view of the lecturer and the student (Dunkel and Davy, 1989). *GroupNotes* encourages this expected behaviour by displaying in real-time the quality, quantity and nature of any notes taken to all other group members. Any off-topic notes are immediately available to others in the group who can provide feedback, either passive or aggressive, to ensure that future notes remain relevant to the lecture content. While writing in a *GroupNotes* workspace is the primary indicator that the individual is contributing to the shared goals of the group this may not always be the case. Depending on working arrangements of the group it may be that a specific group member may be assigned a role where they are not expected to make many notes. As long as they are

contributing to the quality of capture of information in line with the group expectations then they are contributing to the note taking.

A response from a participant in the Livenotes experiment (Kam et al., 2005) identified that knowing their notes were to be accessed by another meant that the notes were created differently than if they were for personal consumption alone, and the speed of note taking was reduced because of this. This limitation is expected to be overcome quickly in each group as they have chosen to work together for an extended period, not just a single lecture, and additional effort will be expended in understanding the particular styles and shorthand notations of the other group members in order that they receive the greatest benefit both during and after the lecture.

Note Making

As part of being in a group it is expected that in many instances there will be greater preparation before the lecture by the individual, such as completion of required readings or assignments and any scheduled homework. This preparation would be undertaken in order that the quality of the individuals work during the lecture will meet with the approval of the other group members. The end result of this preparation should mean greater structure to the notes generated. The notes will have now moved from being a linear recording of the information presented to a more logical and structured capture of information which matched their individual understanding of the content. For those students who continue to take notes in the order delivered by the lecturer the access to the notes of their fellow group members providing additional information, including insights and examples, will encourage the review, and rewriting of those notes to accurately reflect current knowledge on the content delivered.

Note Sharing

Sharing notes with at least one other person involves discussion of those notes and means that alternative opinions on the content meaning are explored and either agreed with or amended as required. This solution has the sharing of the notes already built in and provides the access to the author to discuss the content with. A working relationship is already formed between group members to discuss the notes post-lecture and further develop new, and confirm existing, knowledge.

3.3.3 Interaction should Promote Good Practice

This section identifies the manner in which the *Seven Principles*, other than principle 1, known to be good practice in undergraduate education (Chickering and Gamson, 1991) are implemented from a peer-to-peer perspective using *GroupNotes*. Regardless

of the best intentions of both the lecturer and students the lecture is not a one size fits all method of knowledge transfer and with the lecture component of a topic potentially accounting for 50% of the formal teaching staff to student contact time, an alternative means of promoting good practice can make a valuable contribution to the learning outcomes of the student.

While it is not expected that all groups using *GroupNotes* will be promoting all possible principles, i.e. not Principle 1, at all times, it is anticipated that at least some of the *Seven Principles* will be encouraged inside each group and will lead to engagement in the lecture content on a continuing basis.

The flexibility of the interface in allowing users to limit their real-time exposure to the volume of information generated by their group members means that Principles 2 – 7 are able to be promoted in real-time as well as post-lecture depending on how the group and the individuals composing those groups choose to work together.

The principles, and a discussion of peer-to-peer promoting of them, are as follows:

Principle 1 encourages contact between students and faculty.
"Frequent student faculty contact in and out of classes is the most important factor in student motivation and involvement. Faculty concern helps students get through rough times and keep on working. Knowing a few faculty members well enhances students' intellectual commitment and encourages them to think about their own values and future plans."

The focus of the *GroupNotes* solution is for the failure of this principle in the lecture room.

Principle 2 encourages the development of reciprocity and cooperation among students.
"Learning is enhanced when it is more like a team effort than a solo race. Good learning, like good work, is collaborative and social, not competitive and isolated. Working with others often increases involvement in learning. Sharing one's own ideas and responding to others' reactions improves thinking and deepens understanding."

GroupNotes will enable students to form a group based on whatever criteria they choose; friendship, academic ability, shared goals, work ethic etc. without compromising the ability of any one individual to work in a manner that suits their own learning style. This self-selected group can then work in a manner which best suits their shared goal of knowledge acquisition by allowing text to be written; drawings to be made and lecture slides to be annotated by these individuals, and with results available to all other group members in real-time if desired. The activities being carried out may be the result of cooperation, all members doing their own thing and pooling the results or they may be a collaborative effort which aims to provide the best result for the group as a whole by designating certain tasks to those best equipped to handle them. Rather than the staff member directing and encouraging cooperation and reciprocity it is the

self-selected members of the group who are organising their own group to meet their own goals in a manner that best suits them in achieving their goal.

A major positive for the group nature of this solution is the availability of others to share one's own knowledge, experiences and learning. The lecture environment will to too fast for many to do much other than keep up with the lecture content being delivered, with an occasional quick look at another group member's notes to validate or challenge one's own knowledge. While the real-time interaction may not be possible for all, the availability of others to discuss the lecture content post-lecture is already in place. You have a working relationship with your group members, and already have access to their notes, meaning you have a ready made audience to share and discuss both your own and their knowledge in relation to the lecture content and the opportunity to construct new knowledge as appropriate and verify your own existing knowledge.

Principle 3 encourages using active learning techniques.
"Learning is not a spectator sport. Students do not learn much just sitting in classes listening to teachers, memorizing prepackaged assignments, and spitting out answers. They must talk about what they are learning, write about it, relate it to past experiences, and apply it to their daily lives. They must make what they learn part of themselves."

As identified in discussing the group based structure of *GroupNotes* promoting Principle 2, reciprocity and cooperation, the availability of the knowledge, or the lack of knowledge of a group member compared to their peers; the examples identified and examples expanded upon by the other group members encourages active learning by being available when needed.

GroupNotes provides a platform to not only take notes as quickly as traditional pen and paper but also provides the opportunity for viewing other group member's notes and drawings illustrating their own knowledge and experiences regarding the same content. Providing this in real-time, with the individual able to access them at the appropriate "teaching moment" during the lecture enables the student to also query others in their group when they are unclear on a certain aspect of the content or to explain their own knowledge to others as required in order that they keep up with the lecture content. The ability to view and discuss content of which they are uncertain, or disagree with, at the time of their choosing, either in real time or after the lecture when reviewing the entirety of the groups notes brings multiple perspectives to what is traditionally an individual endeavour. As with the discussion of Principle 2; the availability of a ready made group who share a common goal of capturing information and creating knowledge is precisely what is required. In all groups this is available post-lecture while some groups will also have it available in real-time.

Principle 4 advises giving prompt feedback.
"Knowing what you know and don't know focuses learning. Students need appropriate

feedback on performance to benefit from courses. In getting started, students need help in assessing existing knowledge and competence. In classes, students need frequent opportunities to perform and receive suggestions for improvement. At various points during college, and at the end, students need chances to reflect on what they have learned, what they still need to know, and how to assess themselves."

Chickering and Gamson (1991) identify this as knowing what you do, and do not know, as well as identifying opportunities for improvement. The ability to view the content generated by the other members in your group as it is created provides immediate feedback in the form of validation of your own knowledge if they agree with you. If the content of your other group members does not agree with your knowledge you have the opportunity to investigate further and create new knowledge through a negotiation process which may involve just reading the content they have generated and accepting it into your own world view or it may involve asking questions. Your questions may be asked in your own workspace or you may choose to ask a question in the workspace of another group member who you consider the most likely to be able to provide to you the answer you require at the time to allow you to progress. It may be that it is another group member who provides the right explanation with the right example which allows you to consolidate this knowledge after further review. Your ability to assist your other group members when they require assistance in understanding something will highlight to yourself where you have opportunities to improve your knowledge. If you can quickly provide sufficient knowledge, an example or experience to allow a fellow group member to continue being engaged in the lecture, and not give up due to the content no longer making sense then you are identifying if you need to improve in those areas. Prompt does not have to mean immediate. The availability of the group to discuss any areas of concern at a later stage when the group member has had time to review their own and other's notes also qualifies as prompt.

Principle 5 emphasizes time on task.
"Time plus energy equals learning. There is no substitute for time on task. Learning to use one's time well is critical for students and professionals alike. Students need help in learning effective time management. Allocating realistic amounts of time means effective learning for students and effective teaching for faculty. How an institution defines time expectations for students, faculty, administrators, and other professional staff can establish the basis for high performance for all."

Chickering and Gamson (1991) declare this means learning to use ones time well; time management being a skill critical to both students and professionals. The major factor responsible for a lack of engagement during lectures is the absence of interaction however with *GroupNotes* providing the ability to gain insight into another group members understanding during the lecture this interaction is returned. While this may not provide the impetus to remain on task on all occasions, the student may be unwell or tired etc. there are other factors present which will contribute to the students

remaining on task. The principle agent paradigm states that a agent (student) will withdraw effort from a task whenever the supervisory agent (principal) is removed. In this case the supervision is always present in the form of each other group member. The fact that each student in the group is both an agent and a principal at the same time negates the likelihood of reducing effort on the task at hand and performing unrelated tasks such as checking Facebook, Twitter, surfing the net etc. because these activities would require leaving the *GroupNotes* server; an action that is immediately apparent to all other users in the group. The dynamics of the group, since it is self-selected and has a shared purpose of attaining a specific goal, will encourage time on task through implicit motivation to perform at the agreed level.

A further aspect to *GroupNotes* providing an environment that emphasises time on task is that it runs on a dedicated server that does not permit access to the internet. There will be no Facebook notifications, no Twitter updates, no new emails, no checking with Wikipedia to see if the lecturer is right. All of the distractions that are designed by the applications listed, and others, to attract your attention towards them and divert away from your current focus are removed. As long as the intent to concentrate on the lecture is present when the lecture begins then there is no competing application for your attention permitted to access the internet at the same time.

The Theory of Reasoned Action (TRA) (Fishbein and Ajzen, 1975) states that the best indicator of a behaviour is the intention to perform that behaviour. If your intention is to engage with the lecture and you login to *GroupNotes* then you are removed from external internet distractions that may shift your attention.

An extension to TRA is the Theory of Planned Behaviour (TPB) (Ajzen, 1991) which includes perceived behavioural control as a factor in predicting behaviour. TPB states that attitude toward behaviour, subjective norms, and perceived behavioural control together shape an individuals intentions and behaviour.

By logging into a *GroupNotes* session the student's intended behaviour is to remain engaged with the lecture content and contribute to the efforts of the group in capturing information and developing new knowledge or confirming existing knowledge.

The subjective norm of the group is the individual student's perception about the intended behaviour, which in itself is influenced by the judgement of significant others. In this case the significant others are the lecturer, who expects you to take notes, and the other students in the group, who also expect you to take notes or otherwise contribute to the efforts of the group.

The perceived behavioural control is the individual students perception of the ease or difficulty of performing the expected behaviour. In this case it is the ease or difficulty of contributing to the efforts of the group in taking notes or other agreed tasks e.g. drawing the diagrams, generating possible exam questions etc. The expected behaviour is not beyond the capacity of an undergraduate student.

GroupNotes introduces significant measures to assist the student to remain on task. The use of a dedicated server that does not permit access to external distractions such as email, Facebook, YouTube etc., means that the student must actively take steps to access those services; something that goes against their declared intention by forming a group and accessing the *GroupNotes* server in the first place. Accessing those services will also mean logging off the *GroupNotes* server,; an action that is immediately notified to all other group members. Additional pressures in the form of intrinsic motivation (Deci and Ryan, 1985) by the student to either not let their peers down by stopping their contribution to the group for even a short time, or to make them happy by continuing to contribute, means that the individual will in most instances continue with the behaviour they intended, taking notes and contributing to the efforts of the group.

Principle 6 is the promotion of high expectations. "Expect more and you will get it. High Expectations are important for everyone – for the poorly prepared, for those unwilling to exert themselves, and for the bright and well motivated. Expecting students to perform well becomes a self-fulfilling prophecy when teachers and institutions hold high expectations of themselves and make extra efforts."

The Theory of Bounded Rationality (Simon, 1972) implies that an individual does not always aim for an optimum solution, they aim for a solution that is the best they can achieve with the resources they have available and are willing and able to contribute. On a cold wet morning when you know you should go for your morning walk you can decide it is not needed today and go back to sleep, and quite often do. If someone is expecting you to meet them for the morning walk it is a different matter and you will get up and meet them. It is the same forces that will apply to the maintaining of the standards agreed to with others in your group. You have selected, and they have accepted, a group of individuals you want to work with for the shared goal of acquiring new knowledge to a predetermined high standard and regardless of your attitude on the day you will strive to meet the commitment you have agreed to. High expectations do not just mean a high grade but may also relate to work effort and to improving on your current standard. Joining a group of Distinction level students when your previous achievements have been at a Pass level but making the commitment to achieve at least a Credit and then achieving that meets the intent of this principle. *GroupNotes* relies on the psychological pressures inherent within self-selecting groups to communicate the expectations of the group. The motivations of the members of the group to assist themselves and others in meeting their shared goal coupled with the instant access to, and knowledge of, the activity of the other group members in real-time is expected to maintain the agreed commitments of the group.

Principle 7, respect for diverse talents and ways of learning.
"There are many roads to learning. People bring different talents and styles of learning to college. Brilliant students in the seminar room may be all thumbs in the lab or art

studio. Students rich in hands-on experience may not do so well with theory. Students need the opportunity to show their talents and learn in ways that work for them. Then they can be pushed to learning in new ways that do not come so easily."

Respect for diverse talents and ways of learning is the primary reason for this research as the belief that the one-size-fits-all lecture is appropriate appears illogical given the increasing diversity of the lecturers and the student population. In the circumstances where there is a lack of interaction and with a real or implied prohibition on talking the only option available is to provide a solution which does not affect or require any change from the lecturer themselves, either in preparation or behaviour. *GroupNotes* provides a platform to allow for social interaction to occur quickly and silently without providing any disruption to those not involved. The examples provided above highlight the suitability of the platform for group members to pursue a shared goal where all students are willing and able to deal with multiple channels of information simultaneously; something obviously this is not the case. For those students *GroupNotes* provides the flexibility to allow the individual the control of their own device interface. The individual user, based on their own learning style, preferences and abilities to cope with multiple information sources will determine how many of these information sources they access at any given moment, and do so knowing they are not impacting others in their group from choosing their own preferred interface layout. While their device will receive all the content generated by the other members in their group in real-time it is the individual who decides when and how to view it.

GroupNotes allows for the formation of a group using any criteria its members choose; cognitive ability, same ethnic background, existing working relationship or friendship, all are valid choices. The core requirement is the desire to work with each other to achieve a higher result for the group. This desire to work with selected others also brings the different talents and learning methods of the group members into focus. Student A in Group 1 may choose to make almost verbatim notes in their area while Student B, who is not a fast maker of notes may just make an occasional note on what they need to follow-up on. Student C may not take notes at all and may simply write down questions about the information being provided to determine what they remember of the lecture and where they need follow-up. Student D may make a mind-map of the content being delivered using colours and shapes for emphasis and grouping. Student E in Group 2 may choose to use the Cornell Method for note taking while Student F in the same group may choose to take notes in a linear fashion. Student G may have done all the required preparation and generate notes only related to their own lack of knowledge; heavy in some areas and light or non-existent in others. Student H may not take structured notes at all; they may have an assigned role within the group which is to concentrate on the lecturer and identify where particular emphasis, either oral or visual, is added to the content being delivered. The self-selecting nature of the group allows the members to understand each others strengths, weaknesses and preferences

in developing knowledge and accept and respect these differences. This principle of respecting diverse talents and ways of learning will not be universally adopted by those using *GroupNotes*; there will be many groups formed of students who share a common background and way of doing things that will never encounter this diversity however assigning students to groups will remove the positive intentions that people wanting to work together bring to the solution at the expense of forcing a level of diversity.

3.4 Conclusion

GroupNotes has been designed to meet the constraints and requirements as outlined in Chapter 2 and is based on sound principles relating to good practice in undergraduate education, promotion of practices known to be educationally advantageous, and is based on established principles of Psychology.

The next chapter presents the *GroupNotes* interface and identifies the various manners in which it can be altered to permit a diverse group of students to work together in a lecture session.

Chapter 4

GroupNotes Interface

The first section of this chapter identifies the features of the *GroupNotes* interface and the manner in which it is able to be customised by each user. The second section presents four different group scenarios to illustrate how students can choose to work together using *GroupNotes*; three where the students are all producing their own notes and a further one where each member is assigned a specific responsibility. The final section of the chapter discusses which of the *Seven Principles* are being implemented, or encouraged, for each of the four scenarios outlined.

4.1 Maximum Flexibility

The design of *GroupNotes* provides a mobile platform that allows the social interaction common to learning (Bransford, Brown and Cocking, 2000) into the lecture environment. It is a multi-touch, multi-device, multi-user, multi-document interface that: (1) allows a user to naturally operate a touchscreen with common multi-touch gestures; and (2) facilitates real-time cooperation and collaboration among a small group of students, while emphasising each individual's control of the multi-document interface.

GroupNotes provides the individual user the flexibility to control the level of interaction they are exposed to thereby allowing them to work in the manner which best suits themselves. At the same time they are able to contribute to the engagement and learning outcomes of the other members they have selected to work with, regardless of the criteria they have chosen to assemble their group. Individual users are provided all content generated by other members in their group in real-time and in a form that enables immediate identification of the author. The individual chooses when and where to access this information, depending on their own ability and preferences. The interface as presented in Figure 4.1 has incorporated features which were seen as important by the authors and from a needs finding questionnaire delivered to a class of undergraduate computer science students. The design is built on the premise that you are

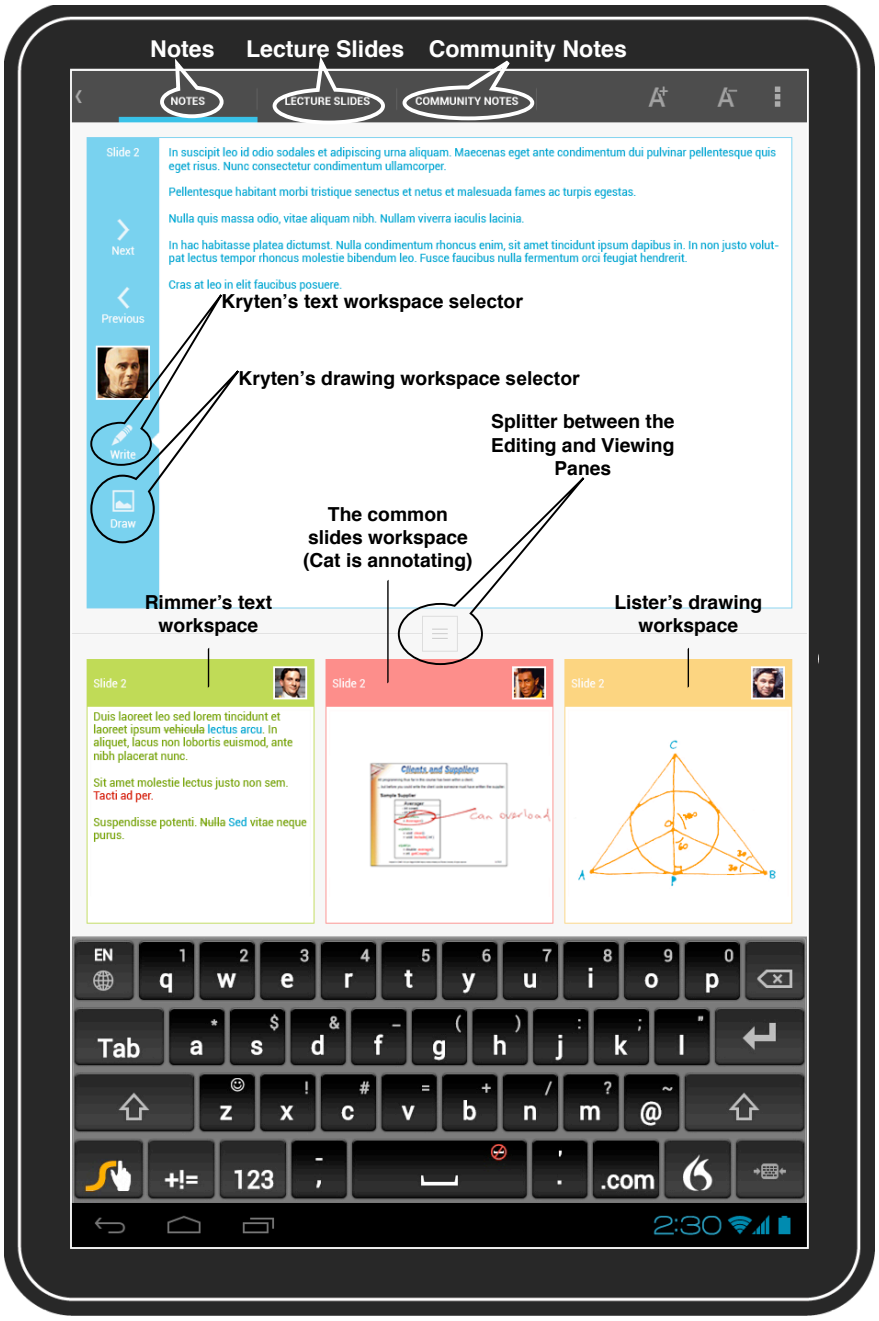

Figure 4.1: Multiple Shareable Individual Workspaces

able to edit any Note, either text or drawing, belonging to any group member, at any time.

The *GroupNotes* interface makes use of the gestures familiar to mobile device users to navigate and interact with the device. A continuous entry keyboard interface, pioneered by Swype (Nuance Communications, 2010), is included for the speed of text entry and makes it comparable with the traditional handwritten method of note taking involving pen and paper. Individual group members are identified by a picture, or avatar, their chosen username, and a unique colour which persists throughout the entire session and is consistent on all devices active in the group. This colour identifies all content, written or drawn, by each group member to all other group members.

The structure of group members Notes, either drawing or text, is to replicate the structure of the lecture. Individuals provide comment in either the drawing or text workspace, referred to as a Note, which corresponds to the slide provided by the lecturer, e.g. comments on their second page of a Note relates to content delivered by the lecturer from their own second slide. As the lecturer begins a new slide each group member adds a new page to their Note where they start commenting on the new content. This means that not everyone will start a new Note at the same time as some members will still be finishing content from the previous slide. It will however, associate all content from a particular slide into the same area of the Community Notes; the complete capture of all generated content by the group in a session (see Section 4.1.3).

As individuals are able to edit other group member's Notes the notion of individual ownership of a Note is required to keep comments relevant to where they are intended. An individual who starts a Note owns that Note, and all comments inside it, regardless of who made them. This means that when viewing the content of a Note you may see multiple colours in text and in drawings. This makes sense for the reading of the content, since a modification or addition to an individual's Notes will generally only make sense when you see them in context.

All content generated, either in their own or others notes, occurs in a local space and is transferred to a server in the cloud where synchronisation takes place. This is then delivered to all other group members (Shen and Reilly, 2012).

A session consists of a small number of students, typically 3 - 4, and is limited by the cognitive complexity of keeping up with both the lecturer and their peers. A session of n users shares $2n+1$ editable multi-page documents (the slides document plus each Note consisting of a text and a drawing document) that can be jointly edited by the n users in real time. The n users are full members of this session and have full access to all the shared documents.

Synchronisation of documents within a session is based on Operational Transformation (OT) (Sun and Ellis, 1998; Shen and Sun, 2002; Li, Li and Sun, 2004), an optimistic lock-free technology for consistency maintenance and concurrency control in

advanced groupware systems. Details of synchronisation at the server side are discussed in chapter 5.

The *GroupNotes* interface comprises three separate tabbed sections, a Notes area, a Lecture Slides area and a Community Notes area.

4.1.1 Notes

Figure 4.2: View all information sources

The Notes tab shown in Figure 4.2 comprises an Editing Pane and a Viewing Pane divided by a splitter, and the keyboard to enable immediate keyboard interaction. The Note, when visible in the Editing Pane, contains a vertical identification bar on the left. This coloured bar identifies the slide number to which the content of the Note refers, the unique colour associated with all content generated by the owner of the Note, an avatar or picture of the owner, and their username. In Figure 4.2 the blue identification bar has a picture of Kryten; this means that any content generated using blue text or drawing has been authored by Kryten. It also means that any content generated into a Note that has a blue identification bar will remain associated with that Note. While the Note remains in the editing pane it also includes navigation arrows to traverse backwards or forwards through the available pages and access to the two available workspaces, text or drawing. The forward navigation arrow also generates a new empty page if there are no more available to access in advance. This page is then ready for new content as the lecturer continues with new slides. Content generation is only possible when a

Note is visible in the Editing Pane and is limited to a single Note at a time. The user who created the note would generate content to which other group members may add, either through additional comment or through emphasis of the originators content by such means as; highlighting, or underlining the text, or drawing using their own unique colour. They may also choose to disagree with the originators content. They are unable to delete content they did not create, only the original author has that permission, but they are able to strike-through it if text, or if a drawing, by drawing over the original using their own unique colour. The use of unique colour to identify the contribution of each member of the group allows each user to determine how much weight they give to that content in relation to their own knowledge validation or construction.

The Viewing Pane will show the individual Notes of the other group members which

Figure 4.3: Minimise Viewing Pane

were most recently edited. In the example provided in Figure 4.2 pages belonging to Cat (centre) and Lister (right) are showing Slide 2, the same as Kryten in the Editing Pane however Rimmer (left) has not yet commenced to page 2; the text on page 1 is the most recent that was worked on and is therefore shown. The splitter dividing the Editing Pane from the Viewing Pane is included to provide for the individuals who find the viewing area a distraction. The splitter is provided to enable the reduction of the on-screen area of the Viewing Pane until only the identification bars, now horizontal across the top of each Note, of the available group members is visible (refer to Figure 4.3). To return these Notes to the point that content is once again visible is a matter of dragging the splitter up until the Viewing Pane is at the desired height (Figure 4.2).

The identification bar of the Notes shown in a radar view within the Viewing Pane is a subset of that shown when in the Editing Pane. Rimmer in green, Cat in red, and Lister in orange in 4.2 show the reduced information provided of only the unique colour, avatar or picture, username and slide number to which the content within refers. This reflects the deliberate lack of interaction available to users when a Note is in this Viewing Pane area.

Content within an individual page shown in the Viewing Pane is scrollable within that Note but is not editable, nor is a different page from that same group member able to be selected from within the Viewing Pane. Access to other than the most recent content generated by a group member is available by accessing the read-only Community Notes tab (Figure 4.6 - see Section 4.1.3). If there is the intention of editing then this can only be accessed through dragging the Notes of that group member into the Editing Pane. As soon as a user has a Note in the Editing Pane they are able to navigate backwards and forwards through the pages of that Notes' entire session history from the first to the most recent page and are able to generate their own content into those pages wherever they choose.

4.1.2 Lecture Slides

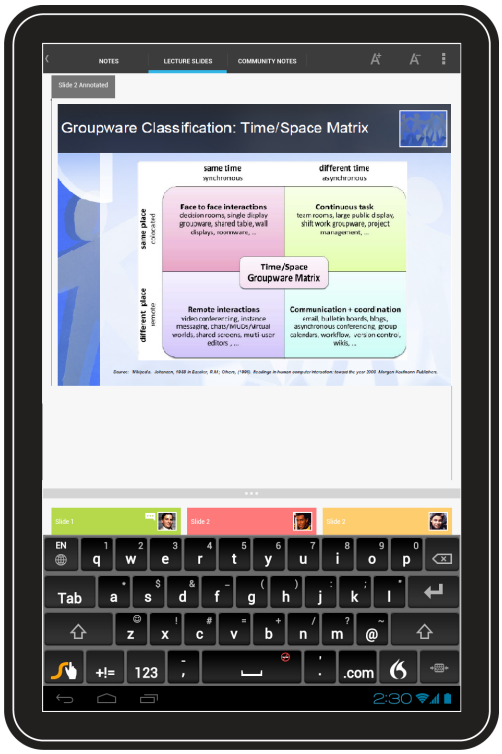

Figure 4.4: Viewing of Lecture Slide

The second tabbed area of the interface is for Lecture Slides, if they are provided, or as a group workspace, if they are not. The content in this tabbed area differs from

a Note in that it is owned by the group and any member can annotate the slide as required. Depending on the wishes of the group this may be left untouched (Figure 4.4) and only amended as directed by the lecturer, or it may be something that is annotated by one or more members as part of the group's working arrangement with identification of the author content provided by the group member's unique colour. The inclusion of the lecturer slides is important for two reasons. Firstly it is these slides that will be incorporated into the finalised Community Notes - see Section 4.1.3 – and therefore must be accurate at the time the lecture is delivered. Any modifications required by the lecturer, such as correcting a mathematical formula, an incorrect date or some other important point which is important to the completeness and correctness of the slides would be performed here. The second reason is to provide greater flexibility for the users of *GroupNotes* in their preferred manner of taking notes; the option of annotating the lecture slides. The content of these annotated slides is still available to other group members when this tab is selected, and also through the Viewing Pane if another group member has, as their most recent task, viewed or edited the lecture slide.

In the instances where the lecturer does not provide slides as part of their normal lecture routine, the Lecture Slides tabbed area is available to the group members as a shared whiteboard (Figure 4.5). Depending on how the group members choose to organise their own contributions this area may not even be used.

Figure 4.5: No Lecture Slide provided

4.1.3 Community Notes

The final tabbed area is Community Notes and comprises all content generated during a session. The information is presented differently depending on whether the lecture is continuing or has concluded. While the lecture is in session all content generated in the pages of a Note is delivered in real-time to its own section of the page of the Community Notes tab to which it is associated (Figure 4.6). This allows a user to view the entirety of an individual's thoughts along with any additional comments by others related to a specific lecture slide content in a single view, and then do the same with each other group member's generated content for the same slide. In the example shown in Figure 4.6 content is visible from all members except Rimmer; this is due to Rimmer still working on Slide 1 and not yet having created a Slide 2 to record any content(Figure 4.2, left editor in radar view).

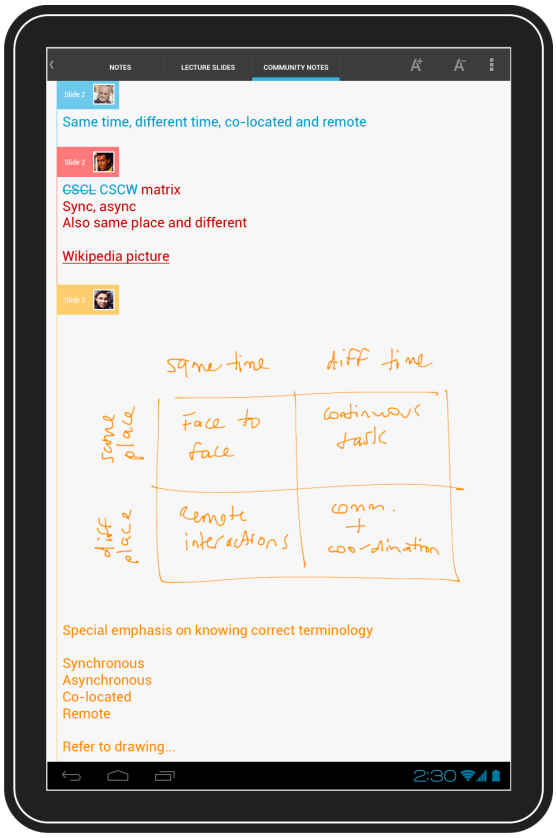

Figure 4.6: Real-time Community Notes

The second stage of the Community Notes is delivered when the last entry to the Notes has been completed by all group members and the lecture is concluded. At this point a single PDF document, the Finalised Community Notes, is created. The structure of this document is to provide the lecture slide, annotated or otherwise, (if it was made available) or the content generated in the Lecture Slide workspace if any, then

Figure 4.7: Finalised Community Notes

followed by the Notes of each group member specific to that slide number as described in the previous paragraph and illustrated in Figure 4.7.

4.2 Scenarios

A major design criteria in developing *GroupNotes* was to allow students to form groups based on whatever criteria they chose, yet still allow them to work in a manner that would not negatively impact their own learning efforts. In this section four scenarios are presented that cover the types of work practices expected within the groups; three where the students are all producing their own notes and a further one where each member is assigned a specific responsibility. The examples provided all assume a group size of four however the number in the group is determined by the group. Testing included groups of two, three and four.

All Members take their Own Notes

Scenario 1: consists of students who have the Viewing Pane hidden at all times. Each student takes their own notes in isolation as is the current practice in a lecture.

Scenario 2: consists of students who, in contrast to Group 1, have the Viewing Pane visible at all times. Each student is taking their own notes but is also viewing real-time content being generated by each of the other group members. Two of the members are coping with viewing the extra content easily and are even able to interact with other users Notes and add to or amend that content as required. The remaining two are able to generate content in their own area only but are able to view the content of each of the other group members in real-time.

Scenario 3: consists of students who generally have the Viewing Pane reduced to just showing the Identification Bar. When the need for a real-time interaction occurs such as checking the notes of their fellow group members to confirm something it is raised and then lowered again when the interaction is finished.

Specified Roles for Each Member

The first three groups (outlined above) are consistent in that all group members are taking their own notes, however there are expected to be situations where groups assign a specific role to certain, or all, members of the group to meet the needs of the group. The needs of the group may be to maximise the capture of information, or it may be to allow a group member to contribute in a specific manner that emphasises a particular strength or talent they have such as drawing ability or exceptional data entry speed. Depending on the role of the group member this may not require that their Viewing Pane is open at all times. If the role the student is assigned does not require the viewing of the work of others in real-time, and the student does not feel capable of doing this, then there is no requirement that they do.

Scenario 4: also consists of four members however there are only two Notes areas where content is being generated. Student A is paired with Student B while Student C is paired with Student D. Student A and C are both assigned the role of taking any notes and making any drawings required. The role of Student B and D is to read the notes of their partner as they are being generated and see if they capture the content being delivered. If the selection of content and terms selected to be written by their partner match their own understanding then they do not have to do much but follow along however if they do not match then they must themselves generate content into the Note. This may take the form of adding additional words, deleting (strike-through) words, or emphasising content by underlining, bolding or highlighting existing words. Being able to concentrate on the words of the lecturer, and therefore more able to identify the spoken organisational cues to the importance of specific lecture content (Titsworth and Kiewra, 2004), Students B & D are ideally placed to ensure that the critical information is both adequately recorded and its importance highlighted.

There are many different roles that the group member may be assigned. A variation on the roles of the members in Scenario 4 may have Student A tasked with taking notes while Student B does all drawing and diagrams required. Student C reviews those notes and drawings in real-time and makes any required additions or corrections while Student D annotates the slides provided by the lecturer. Further roles that students may adopt could include; ensuring someone was watching the lecturer for visual clues as to the importance of certain content–something that can be missed when concentrating on generating the notes instead of watching the lecturer and generating notes as required. Another role could be creating a question that would encompass the content delivered in relation to the slide, while yet another could entail a student just doing all drawings that are required.

The roles would depend on the existing knowledge, skills and abilities of the group members being sufficient to meet these objectives in a manner that did not impact their own learning in a negative manner, and that they were prepared to accept.

4.3 Meeting the Principles

It is not expected that each of the *Seven Principles* are promoted in each scenario however at least some will be, and that is what will keep the students engaged in educationally meaningful activities. While not all groups, or all members in groups, will be able to use the real-time interaction that *GroupNotes* provides, the information is still available post-lecture. Also available is the group structure to facilitate review and discussion of the information recorded and the creation of new knowledge, or codifying of existing knowledge.

These *Seven Principles* are listed below and include a discussion on how the use of *GroupNotes* is promoting them. The group structures, outlined in the Scenarios identified in Section 4.2, are used in the discussion to identify the different manner in which these Principles may be promoted from the student-to-student perspective.

P_1 Encourages contact between students and faculty

"Frequent student faculty contact in and out of classes is the most important factor in student motivation and involvement. Faculty concern helps students get through rough times and keep on working. Knowing a few faculty members well enhances students' intellectual commitment and encourages them to think about their own values and future plans."

No contact occurring here; that is the point of *GroupNotes*.

P_2 Develops reciprocity and cooperation among students

"Good learning, like good work, is collaborative and social, not competitive and isolated. Working with others often increases involvement in learning."

The build-up to the testing of *GroupNotes* provided the opportunity for the students to get a sense of how they could cooperate in what is traditionally a singular endeavour. A problem with lectures that was consistently voiced was the lecture slides where there were too many dot points and not enough time to write them all down. A strategy quickly evolved where the individuals knew who was responsible to ensure coverage of notes if a lecture slide contained more than a set number of dot points. The groups had different strategies to ensure this; a group of 4 knew which two in their group made sure to capture all the even numbered dot points and who captured the odds. Another group knew who started capturing the dot points from the top down and who started from the bottom and worked up. Some groups detailed that the student who captured the dot point also generated the notes for it. The student who was still writing notes on the dot points from the top half of the slide was not concerned that they were missing the content from the bottom half; their fellow group members were doing that for them. Those responsible for the dot points in the bottom half had the dot points written before the lecturer discussed them and had to elaborate on those points only. This was the most obvious example of cooperation witnessed during the testing of *GroupNotes*, however the reciprocal nature of this strategy is also important. The group members were trusting in their fellow members to accurately capture the information at a high quality and to share it with them.

"Sharing one's own ideas and responding to others' reactions improves thinking and deepens understanding."

The knowledge that the group members work is to be shared and discussed with others is inherent in the design of *GroupNotes*; real-time sharing is enabled while post-lecture interaction is encouraged through the pre-existing group structure. There is a ready made audience for the sharing and discussion involved in constructing new knowledge.

Scenario 1 has each group member cooperating to provide a comprehensive capture of the lecture content by sharing their notes with all other members of the group as well as receiving the notes of the other group members. At the end of the lecture there are four individual sets of notes of varying quantity and quality available to all group members; three more than would generally be the case. There is also a ready made forum to review and discuss these notes post-lecture.

Scenario 2 also has each group member cooperating to capture all information provided during the lecture however with this style of group there is also the possibility for the individual group members to access, and respond if desired, to the generated content in real-time. The discussion of the content does not have to wait until after the lecturer has concluded. As with Scenario 1 there are four sets of notes and a pre-formed group to discuss those notes and generate new knowledge for the individual, except theses notes will likely include comments generated from a real-time

interaction between group members around specific information provided.

Scenario 3 is identical to Scenarios 1 and 2 in that it has four sets of notes and a pre-formed group to discuss, create and confirm knowledge, however this group chooses some real-time interaction when required. The interaction may be passive and just involve looking at the notes of the other group members when some difficulty with the lecture content occurs, or it may be dynamic and involve editing another group member's Note. In contrast to the group from Scenario 2, where there were members capable of editing Notes other than their own in real-time, there is no expectation that this real-time interaction will occur with this group, but the attempt can be made and will depend on the ability and preferred working style of the members within the group. The individual student is able to generate content e.g., a question specific to a comment by another group member, in that same group member's Note for clarification. If able, that student can respond in real-time or else the discussion must wait until after the lecture to occur. In Scenario 2 there would be the expectation that some response would occur within seconds.

Scenario 4 differs from the three previous scenarios by not having an output of four sets of notes. Depending on the manner in which the group chooses to work there may only be a single very comprehensive set of notes. This scenario most clearly shows the use of cooperative and reciprocal behaviours in meeting a shared goal – a comprehensive set of notes, however the first three scenarios also meet this criteria.

P_3 Uses active learning techniques

"Learning is not a spectator sport. Students do not learn much just sitting in classes listening to teachers, memorizing prepackaged assignments, and spitting out answers. They must talk about what they are learning, write about it, relate it to past experiences, and apply it to their daily lives. They must make what they learn part of themselves."

What examples are being provided by other group members? How is a specific piece of new information being connected to another piece of information or existing knowledge to create new, or to confirm some knowledge? How quickly is this information from other group members available? *GroupNotes* provides the capacity to easily share this information between group members and the group structure created for this sharing extends beyond real-time and the lecture theatre. In addition to the interaction enabled during the lecture, the group now has a ready made audience post-lecture to talk about what they are learning, how it relates to their existing knowledge, and where it can be applied.

Scenario 1 does not have its members implement this principle in real-time however it is available post-lecture.

Scenarios 2 and 3, with the passive viewing of the content of others in the group in real-time allows the individual to identify the examples used and what their peers

are identifying as important at the time they are needing, or wanting, validation of their existing knowledge. It is also providing additional sources of information at the right time to promote new knowledge during the lecture; the 'teaching moment'. Scenario 2 also provides for dynamic application in promoting this principle. A group member can generate content directly in another group member's Note to supply additional information that may be missing or may be useful. The attention of the group member is drawn to new content in their Note area that another group member feels it is important that they are made aware of.

In Scenario 4, members access to the real-time capability of *GroupNotes* provides the opportunity for the application of active learning in real-time, however it is dependent on the role the student is undertaking and their own ability and preferences as to whether this occurs immediately, or waits until after the lecture. The content still provides the examples and insights of their peers to aid in their own creation of knowledge regardless of when they choose to access it.

The most important aspect of *GroupNotes* in promoting this principle is the group structure it provides. The opportunity to discuss what is being learned, and to construct new knowledge, requires a social structure. *GroupNotes* provides this structure within, and external to, the lecture environment with the individual user determining whether to access it in real-time, or wait until after the lecture.

P_4 Gives prompt feedback

"Knowing what you know and don't know focuses learning. Students need appropriate feedback on performance to benefit from courses. In getting started, students need help in assessing existing knowledge and competence. In classes, students need frequent opportunities to perform and receive suggestions for improvement. At various points during college, and at the end, students need chances to reflect on what they have learned, what they still need to know, and how to assess themselves."

'Prompt' is a relative term with regard to feedback. In a real-time environment it may mean immediate, or within a few seconds. In the context of feedback on the learning obtained from the lecture it may mean within hours, or at least on the same day. *GroupNotes* provides the capacity for feedback to be available almost instantly. The nature of the group and how they choose to interact will determine when the opportunity for feedback occurs.

Scenario 1 does not provide feedback within seconds due to the group members all working with the Viewing Pane, and therefore the access to the Notes of other group members is hidden at all times. The feedback provided immediately after the lecture is passive in nature in that there is no existing commentary provided to the notes of each individual from another member. Each note is produced in isolation and represents the information captured by the individual and can be used in concert to identify the likely knowledge required from the lecture. The Notes can

be used to identify any areas where there is not a group consensus on the importance of a specific piece of information as well as identify any area of weakness from the perspective of the individual. The review of these notes can lead to the next stage of the knowledge capture process of note taking by discussion of those notes with others in the group.

Scenario 2 reduces the elapsed time component of prompt feedback to real-time. Both dynamic and passive feedback are now available in real-time in addition to the passive feedback post-lecture as described above. The members in the group have the Viewing Pane open at all times so there is always passive feedback available in real-time. In addition, in the scenario description it was noted that there were two group members capable of contributing content in real-time to Notes other than their own. This means that the feedback can be dynamic; a question, an incomplete entry or an inaccurate statement is able to be viewed and responded to in real-time by another member of the group.

Scenario 3 provides passive feedback in both real-time and post-lecture as described above but does not explicitly provide dynamic feedback. It is possible for this type of feedback to occur but would require one of the students choosing to pose a question in another member's area and that member choosing to reply.

Scenario 4 depends on the roles performed by the group and the abilities and preferred work choice of those members. If the role of a student is to evaluate the Notes of another student in real-time then the feedback is both dynamic and immediate. If the role is to do all drawings, charts and tables required during a lecture, and the capacity, or choice, is to keep the Viewing Pane closed, then the feedback becomes passive and post-lecture.

P_5 Emphasizes time on task

"Time plus energy equals learning. There is no substitute for time on task. Learning to use one's time well is critical for students and professionals alike. Students need help in learning effective time management. Allocating realistic amounts of time means effective learning for students and effective teaching for faculty. How an institution defines time expectations for students, faculty, administrators, and other professional staff can establish the basis for high performance for all."

GroupNotes, across all scenarios, helps to encourage this principle of remaining on task during the lecture by removing the availability of distractions that rely on an internet connection. *GroupNotes* is run on a dedicated server that does not provide access to the wider internet, meaning that the distractions of pop-ups advising that an email has arrived, or that something new has happened via one of the social media channels, such as Facebook, does not appear while *GroupNotes* is active. In addition, if a member leaves *GroupNotes* for any reason, such as accessing local content on their device, this is immediately notified to other members in the group.

Even with the user interface set to have the Viewing Pane reduced to its smallest height the Identification Bar is still visible and the disappearance of one of these Identification Bars, due to a group member leaving, will be instantly obvious to all other members. If a group member is continually absent from *GroupNotes* during the lecture, therefore not spending the allocated time on task, this is a matter for the group to deal with as they see fit. Peer pressure to achieve the shared goal they have agreed to meet, and the knowledge their contributions are being monitored, potentially in real-time, will encourage most students to use the time effectively by remaining on task.

All scenarios are equally affected by the closed nature of *GroupNotes* in restricting the availability of online distractions.

P_6 Communicates high expectations

"Expect more and you will get it. High Expectations are important for everyone - for the poorly prepared, for those unwilling to exert themselves, and for the bright and well motivated. Expecting students to perform well becomes a self-fulfilling prophecy when teachers and institutions hold high expectations of themselves and make extra efforts."

The shared goal of the group determines the 'high expectation' of the group and does not necessarily mean High Distinctions for all. A group may consist of a student who is going to get a High Distinction regardless, and three friends who are currently Credit level students, who think they can do better. Access to the notes of the high achiever; the quality and quantity of the notes, the areas selected as important, when a drawing or diagram was used, is all valuable information whether it is accessed in real-time or post-lecture. Over time the note taking ability of the three Credit level students becomes similar to that of the high achiever in terms of what is recorded and therefore leaves more time to concentrate on the lecturer, to catch some of the visual clues to the importance of specific points, to have sufficient time to understand the content as it is being delivered and to ask and answer questions of the lecturer. The expectations of the high achiever are also challenged in this scenario as they are committed to helping their friends to achieve a higher level of learning. This may mean that their notes may need to be enhanced in certain areas to ensure that sufficient detail is captured to assist their group members. Certain information that may not normally have been included in their notes, as it is already current knowledge to them, may now need to be included. The important points need to be captured as part of assisting the group, not just the important points that were not already known and understood.
The manner in which the group accesses the information in *GroupNotes*, either real-time or post-lecture, is not important, nor is the manner of the individual group member's contribution – equal contribution or undertake a specific role – as long as it is meeting the agreed goal of the group. The motivation, either intrinsic

or extrinsic, to personally achieve, and to also help the other group members to achieve, the agreed expectation, will encourage each group member to do what is necessary to achieve the goal. The knowledge that a group member is able to perform to a certain level encourages expectation from others that at least that same level of achievement will be met in the future, which is then conveyed to the individual. Human nature is to then try to live up to that expectation.

P_7 Respects diverse talents and ways of learning

"There are many roads to learning. People bring different talents and styles of learning to college. Brilliant students in the seminar room may be all thumbs in the lab or art studio. Students rich in hands-on experience may not do so well with theory. Students need the opportunity to show their talents and learn in ways that work for them. Then they can be pushed to learning in new ways that do not come so easily."

The group members in Scenarios 1 - 3 are each responsible for taking their own notes but this does not mean they are uniform in their approach to capturing the information provided during the lecture. The many different levels of knowledge, skills and abilities of the students in a group will mean that there will be many different approaches to taking notes and a wide range in the quality and quantity of those notes. The importance of the group being self-selecting means that those differences are accepted and embraced. The exposure to other group members different methods of capturing information and of the information deemed important to capture is a learning experience in itself. Higher performing students may find additional information and personal examples from their lower performing colleagues to be useful, while the lower performing members have the opportunity to identify the types of notes taken by a high achiever. Questions unrelated to the specific content of the lecture will be asked such as; "What specific content did they capture?, How many notes did they take?, What style of notes were taken?, How did they know that certain content was important?". The viewing of the notes of a higher achieving colleague, and being able to identify where they are superior, will alter the note taking strategy of the lower achieving student to potentially become more effective. In time they will themselves produce more effective notes, and the subsequent reviewing of these notes should result in a higher learning outcome for those students.

The composition of the group in Scenario 4 can be from any of the type of student and with any mix of knowledge, skills and abilities.

The student (Student A) who is capable of capturing all the content delivered but struggles to understand much of it because they have had no time during the lecture to listen to the content-just capture it, would benefit from someone like Student B. Student B has a permanent or temporary disability that limits their capacity to take notes quickly but is always prepared for the lecture in terms of having performed

the necessary readings and other homework - they know what to expect from the lecture. Student B auditing the notes of Student A to ensure completeness and correctness, and to highlight the important points, would provide benefit to them both. If the same group also contained Student C and D the information capture is further enhanced. Student C who has the skill for identifying the relevance of the material being delivered-not too many notes so that they are unable to concentrate on what the lecture is delivering, particularly the visual clues to the importance of certain content, and Student D who can barely capture the basics of the lecture in written form but produces mind-maps that collect all the critical points and connects them. If these four individuals chose to work together the end result would be two sets of written notes and a mindmap. One set of notes complete and externally validated in real-time, with the other the work of an individual who has a track record of taking efficient and effective notes. The reviewing of these notes post-lecture exposes each group member to the strengths of the others and to different ways of accomplishing the capture of information.

In addition to gaining an understanding of, and respecting the different methods of capturing information and building knowledge from a lecture, working with others provides not only the opportunity to construct knowledge from the more complete capture of the lecture content but also to identify, and learn, alternate means of efficiently capturing information themselves.

Student A may benefit by being exposed, post-lecture, to the auditing of their notes by Student B and to the more efficient notes of Student C. Identifying what content is important and what did not need recording will allow them to improve their future note taking and also to allow more time understanding the content during the lecture as it is presented. Their exposure to the mindmaps of Student D can also have an impact on the manner their notes are recorded - sometimes a picture is worth a thousand words, and this can be implemented into their future note taking strategy.

Student B now has a valuable resource, the notes of Student A, and has also validated their own knowledge, gained from their own preparation for the lecture, through the process of auditing the notes as they were written by Student A. Viewing the notes from Student C is important to also externally validate the knowledge gained, and where additional information is required. Student D takes far less notes than Students A and B by creating mindmaps and connecting the important points – something that Student B may be able to incorporate, given that they have a disability that limits their capacity to take notes quickly.

Student C has an extra set of notes to ensure that nothing was missed in their own, as well as external validation of the importance and correct interpretation of the information provided, or a discussion point with others to negotiate new knowledge where a conflict occurs. The mind-maps of Student D provide either

further validation, or a challenge to, the knowledge of Student B as well as another method to capture information that may prove useful in the future.

Student D has access to two complete sets of notes to match their own information capture against. They also have an idea of what is deemed useful and important information provided by the lecture in a form they are not currently capable of capturing under the time constraints of a lecture. Viewing these other sets of notes and assessing the amount of words required may alter their own strategy. They can still use the mind-maps they are comfortable with but there may be additional, or less, content required to be noted.

The important factor is that the group is aware of the strengths, weaknesses and preferences of each member and that the roles assigned to the members take this into consideration.

Chapter 5

GroupNotes Backend

This chapter presents the technical solution to the challenges of using a mobile device-based real-time collaborative note-taking system such as *GroupNotes*. The solution allows for a personalised multi-user view through the flexible layout of multiple windows, maximally utilising the available screen real estate, personalised content synchronisation through synchronisation protocols and algorithms based on the operational transformation technique (Sun and Ellis, 1998).

This solution decouples the multi-user interface from the underlying content synchronisation. Users are able to customise the multi-user interface in such a way that best suits their working styles while remaining in a coherent collaborative session. They can customise the content synchronisation policies to flexibly choose the way they wish to collaborate with others and the way others view their contributions to the shared task.

The *GroupNotes* solution to the multi-user interface design is in sharp contrast to the majority of computer-based real-time group editors such as *GROVE* (Ellis, Gibbs and Rein, 1991), *REDUCE* (Sun, Jia, Zhang, Yang and Chen, 1998), *JAMM* (Begole, Rosson and Shaffer, 1999), and *WRACE* (Shen and Sun, 2011), where all participants in a session share the same single editor window. Personalised view is supported through relaxed WYSIWIS (What You See is What I See), which allows participants to view different parts of the same editor window at the same time (Greenberg, Gutwin and Cockburn, 1996). This solution works on large screens but is not suitable for mobile devices whose screens are comparatively small. Personalised view would not be supported if strict WYSIWIS were adopted, which forces all participants to view the same part of the editor window at any moment in time (Stefik, Bobrow, Foster, Lanning and Tatar, 1987).

Some real-time group editors such as *MMM* (Bier and Freeman, 1991) used multiple editor windows to represent a hierarchy of nested editors within each other. The number of editors did not correspond to the number of participants and all participants had

the same view of all editors at any moment in time, that is strict WYSIWIS at all times. Furthermore, text edits into the same editor are floor controlled (Greenberg and Marwood, 1994) and handled in the order in which they were received.

5.1 Personalised Content Synchronisation

In a real-time collaborative note-taking session consisting of up to 4 members, each member owns a dedicated multi-page note. Each note can be jointly edited by the 4 users; therefore, the note-taking session is actually composed of 4 parallel collaborative editing sessions, one for each note. A synchronisation solution is required to keep all members' notes consistent in the session.

Our content synchronisation solution is based on the contextualisation theory and extended from a data consistency maintenance solution for shared Web-based documents (Shen and Sun, 2011) to the synchronisation of multiple notes in the same real-time collaborative note-taking session. Compared to other synchronisation techniques, such as floor control (Greenberg and Marwood, 1994), locking (Knister and Prakash, 1993), transactions (Bernstein, Goodman and Hadzilacos, 1987), causal ordering (Raynal and Singhal, 1996), and serialization (Karsenty and Beaudouin-Lafon, 1993), this solution can not only meet the three consistency properties required for collaborative editing systems: *convergency*, *causality preservation*, and *intention preservation* (Sun and Ellis, 1998), but also the four requirements for satisfying users' diverse interaction and collaboration needs under complex and dynamic circumstances: *fast local response*, *total work preservation*, *unconstrained interaction*, and *customisable collaboration mode* (Shen and Sun, 2011).

In particular, a user can customise how the content should be synchronised by specifying two independent parameters.

1. *out*: whether they want to share their content with other members,
2. *in*: whether they want to accept the content shared by other members, and

The *out* and *in* parameters will be discussed in the following synchronisation protocols and algorithms based on the cornerstone technique called *Operational Transformation* (Sun and Ellis, 1998).

A central server will be used to synchronise the replicas of the shared content across all mobile devices, in addition to other functions such as repository management (Shen, Sun, Zhou and Phyo, 2006; Xia, Sun, Sun and Chen, 2006), session management (Shen and Sun, 2011; Xia et al., 2006), and Note post-processing (Reilly and Shen, 2011). The owner of a mobile device uses the note-taking app on their device to view or take notes. Updates on the Notes - called operations - are broadcast to other devices for

the synchronisation of Notes (subject to the setting of personalised content synchronisation policies). Before presenting the synchronisation solution, we first introduce the operational transformation technique.

5.1.1 Operational Transformation

There are two types of operations involved in editing a Note: $Ins/Del[position, length, text]$ denotes inserting/deleting a piece of *text* of *length* at the *position* in the Note. Updating an attribute of a piece of text, e.g., highlighting the text, is represented by deletion of the text with the old attribute value followed by insertion of the same text with the new attribute value instead of by a new type of update operations, such as those used in collaborative word processors (Sun, Xia, Sun and Chen, 2004) because updating operations in note-taking are not as heavily used as in word processing.

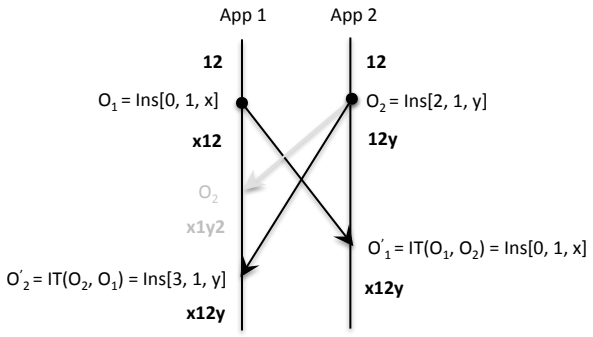

Figure 5.1: Operational transformation illustration

As shown in Figure 5.1, when operation $O_2 = Ins[2, 1, y]$ generated at *App* 2 arrives at *App* 1, it cannot be replayed as-is because the concurrent operation $O_1 = Ins[0, 1, x]$ has changed the context from in which O_2 was defined, i.e., "12", to "x12". Instead, O_2 needs to be transformed against O_1 in such a way that $O_2' = \mathbf{IT}(O_2, O_1) = Ins[3, 1, y]$ has effectively included the impact of the concurrent operation O_1.

$IT(O_a, O_b)$ is an *inclusion transformation* function that transforms operation O_a against operation O_b in such a way that the impact of O_b is effectively included in the parameters of the output operationO_a'. There are four instances of transformation functions, one for each pair of operation types, namely $\mathbf{IT\_II}(O_a, O_b)$ (insert against insert), $\mathbf{IT\_ID}(O_a, O_b)$ (insert against delete), $\mathbf{IT\_DI}(O_a, O_b)$ (delete against insert), and $\mathbf{IT\_DD}(O_a, O_b)$ (delete against delete).

We use $\mathbf{IT\_ID}$ (O_a, O_b) as an example to illustrate the idea. More information about transformation functions can be found in these references (Sun, Xia, Sun, Chen, Shen and Cai, 2006; Sun et al., 1998). For the good of presentation, for operation O $= Ins/Del[position, length, text]$, $\mathbf{P}(O) = position$ denotes O's position parameter,

$\mathbf{N}(O) = length$ denotes O's length parameter, $\mathbf{S}(O) = text$ denotes O's text parameter, and $\mathbf{T}(O) = Ins/Del$ denotes O's type parameter.

Algorithm 1: IT_ID(O_a, O_b): O'_a

```
1: if (P(O_a) ≤ P(O_b) or N(O_b) == 0) then
2:    return
3: else if (P(O_a) > P(O_b)+N(O_b)) then
4:    P(O_a) ← P(O_a) - N(O_b)
5: else if (P(O_a) == P(O_b)+N(O_b)) then
6:    P(O_a) ← P(O_b)
7: else
8:    O_a ← I {I is an identity (null) operation}
9: end if
```

5.1.2 Operation Broadcast

The synchronisation solution consists of an operation broadcast protocol, an operation replaying algorithm, and a set of session management protocols. A Note synchronisation process consists of two sub-processes: broadcast local operations and replay remote operations. As shown in Figure 5.2, the server runs m ($m \geq 1$) collaborative note-taking sessions; each session has up to 4 collaboratively edited Notes. There are n ($n \geq 1$) apps connected to the server and up to 4 apps, e.g. App i, j, k, and l ($1 \leq i, j, k, l \leq n$), can share the same session, e.g. session p ($1 \leq p \leq m$).

For each Note, the server maintains a master Note MN, a master incoming operation buffer MIB storing all operations that should be executed on MN to get its latest state, and a server-side incoming operation buffer for each app involved in the same note, e.g., SIB_i, SIB_j, SIB_k, and SIB_l in session p, storing remote operations that have been received by the server but are yet to be received by the corresponding app. Each app can write into any of the 4 Note at any time, therefore it needs to separately synchronise these 4 Note. For each Note, the app maintains a replica of the Note RN, an outgoing operation buffer OB storing locally generated operations on RN, and an app-side incoming operation buffer AIB storing remote operations that have already been received by the app and will be replayed on RN. In Figure 5.2, RN^i_j, OB^i_j, and AIB^i_j ($1 \leq i \leq 4$ and $1 \leq j \leq n$) are App j's replica, OB, and AIB for note i respectively.

Suppose App k ($1 \leq k \leq n$) is involved in Note r ($1 \leq r \leq 4$) in the collaborative note-taking session p ($1 \leq p \leq m$), the following protocol is executed by the app to broadcast local operations generated on Note replica RN^r_k from OB^r_k. This protocol broadcasts a sequence of operations generated by each app instead of one at a time, significantly reducing the consumption of the mobile device battery and network resources. Separation of outgoing and incoming operation buffers and separation of app-side and

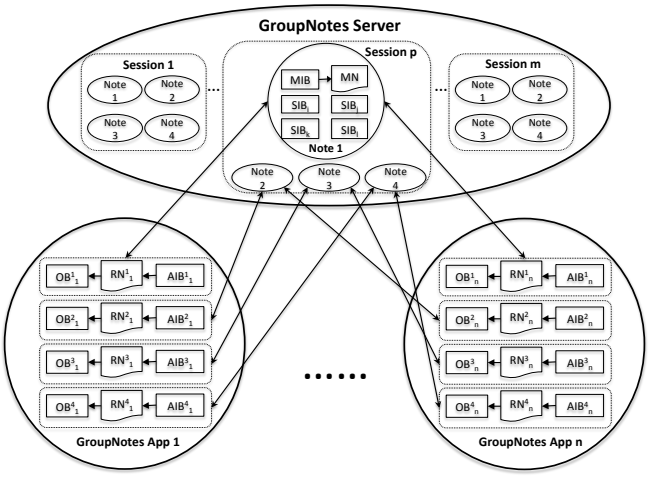

Figure 5.2: Note synchronisation

server-side buffers, reinforced by the Note replicas in the server and across the apps, make the protocol resilient to the network disruptions in the mobile devices.

Protocol 5.1. Operation Broadcast Protocol

1. At App k, move all available operations in OB_k^r to the operation sequence $\overrightarrow{OB}_k^r$. If AIB_k^r is not empty, invoke the procedure **SLOT**($\overrightarrow{OB}_k^r$, AIB_k^r) to transform the operation sequence $\overrightarrow{OB}_k^r$ with the operation sequence in AIB_k^r.

2. App k establishes a network connection with the server and then sends a request $\langle BROADCAST, k, p, r, \overrightarrow{OB}_k^r \rangle$ to the server.

3. When the server receives the request from App k, it performs an atomic synchronisation process on Note r in session p:

   (a) lock Note r, including MN, MIB and all SIB's, e.g., SIB_i, SIB_j, SIB_k, and SIB_l ($1 \leq i, j, k, l \leq$ n);

   (b) if SIB_k is not empty, invoke **SLOT**($\overrightarrow{OB}_k^r$, SIB_k) to transform $\overrightarrow{OB}_k^r$ with the operation sequence in SIB_k;

   (c) append $\overrightarrow{OB}_k^r$ to MIB, SIB_i, SIB_j, and SIB_l;

   (d) if SIB_k is not empty, move all operations in SIB_k to the operation sequence $\overleftarrow{SIB}_k$ and send a response $\langle BROADCAST, \overleftarrow{SIB}_k \rangle$ to App k, otherwise, send a dummy response $\langle BROADCAST \rangle$ to App k; and

   (e) unlock Note r in session p.

4. When App k receives the response from the server, if the response is not dummy, it appends the piggyback operation sequence $\overleftarrow{SIB}_k$ to AIB_k^r.

The **SLOT** transformation control algorithm (Shen and Sun, 2011, 2002), which symmetrically transforms two context-equivalent sequences $Sq_a = [O_{a,0} \cdots O_{a,m-1}]$ (m

$= |Sq_a|$) and $Sq_b = [O_{b,0} \cdots O_{a,n-1}]$ ($n = |Sq_b|$), and returns transformed ones Sq_a^b and Sq_b^a, is defined in Algorithm 2. The **SIT** transformation function, which symmetrically transforms two context-equivalent operations $O_{a,i}^j$ and $O_{b,j}^i$ ($0 \leq i < m$, $0 \leq j < n$), and returns transformed ones $O_{a,i}^{j+1}$ and $O_{b,j}^{i+1}$, is defined Algorithm 3.

Algorithm 2: SLOT(Sq_a, Sq_b): (Sq_a^b, Sq_b^a)

$Sq_a^b \leftarrow Sq_a$
$Sq_b^a \leftarrow Sq_b$
for ($i \leftarrow 0$; $i < |Sq_a^b|$; $i \leftarrow i+1$) **do**
  for ($j \leftarrow 0$; $j < |Sq_b^a|$; $j{+}{+}$) **do**
    $O_{a,i}^j \leftarrow Sq_a^b[i]$
    $O_{b,j}^i \leftarrow Sq_b^a[j]$

    $(O_{a,i}^{j+1}, O_{b,j}^{i+1}) \leftarrow$ **SIT**$(O_{a,i}^j, O_{b,j}^i)$

    $Sq_a^b[i] \leftarrow O_{a,i}^{j+1}$
    $Sq_b^a[j] \leftarrow O_{b,j}^{i+1}$
  end for
end for
return (Sq_a^b, Sq_b^a)

Algorithm 3: SIT($O_{a,i}^j$, $O_{b,j}^i$): ($O_{a,i}^{j+1}$, $O_{b,j}^{i+1}$)

$O_{a,i}^{j+1} \leftarrow$ **IT**$(O_{a,i}^j, O_{b,j}^i)$
$O_{b,j}^{i+1} \leftarrow$ **IT**$(O_{b,j}^i, O_{a,i}^j)$
return $(O_{a,i}^{j+1}, O_{b,j}^{i+1})$

5.1.3 Operation Replay

The other sub-process involved in a Note synchronisation is to replay remote operations stored in an app's AIB. The following operation replay algorithm executes remote operations in AIB_k^r to complete the synchronisation process on Note r by app k.

It is worth pointing out that because local and remote operations need to modify the same replica of Note r at App k, execution of local operations and replaying of remote operations must be mutually exclusive. In case of contention between local and remote operations, local operations must be given the priority to ensure good local response. Otherwise, if all remote operations in AIB_k^r were replayed as a continual stream, local operations would suffer starvation, resulting in poor local response. To minimise the impact on the local response, each remote operation in AIB_k^r should "give way" to new local operations before being replayed.

Algorithm 4: Operation Replay Algorithm

```
1: if (|AIB_k^r|== 0) then
2:    return
3: end if
4: start ← 0
5: if (|OB_k^r|> start) then
6:    end ←|OB_k^r| −1
7:    SLOT(AIB_k^r, OB_k^r[start, end])
8:    start ← end + 1
9: end if
10: repeat
11:    give_way()
12:    lock_replica()
13:    if (|OB_k^r|> start) then
14:       end ←|OB_k^r| −1
15:       SLOT(AIB_k^r, OB_k^r[start, end])
16:       start ← end + 1
17:    end if
18:    O ← AIB_k^r[0]
19:    execute(O)
20:    AIB_k^r.remove(0)
21:    unlock_replica()
22: until (|AIB_k^r|== 0 or HOB's turn)
```

5.1.4 Personalised Synchronisation Policies

If both *out* and *in* are on, each synchronisation process initiated by the app will first execute the operation broadcast protocol to broadcast local operations from OB and then invoke the operation replay algorithm to replay remote operations from AIB on the local replica of the Note. If *out* is on but *in* is off, each synchronisation process will only execute the operation broadcast protocol to broadcast local operations from OB but will not invoke the operation replay algorithm to replay remote operations. Nonetheless, remote operations are still kept in AIB so that they will be transformed with for achieving contextualisation when the operation broadcast protocol is executed. If *out* is off but *in* is on, each synchronisation process will first execute the operation broadcast protocol but with a dummy request (i.e., the request does not piggyback the operation sequence in OB) and then invoke the operation replay algorithm to replay remote operations from AIB. Nonetheless, local operations are still kept in OB so that they will be transformed with for achieving contextualisation when the operation replay algorithm is executed.

Two points are worth clarifying. First, consistency is still achieved even though each app may end up with a different replica of the same Note because causality preservation (ensured by orderly broadcast and transformation) and intention preservation (ensured by transformation) are not affected, and if all operations were executed on all replicas,

they would become identical (same as the master copy). Second, if a user wants to save a Note, after producing the latest master copy by incorporating all broadcast operations on the server, the user will be prompted to save their local replica into their personal space on the server or their mobile device itself as it is likely to be different from the master copy on the server.

5.1.5 Session Management Protocols

The session creation protocol is to be executed when a user wants to create a new collaborative note-taking session, the session joining protocol is to be executed when a new user (i.e. a latecomer) wants to join an ongoing session, the session saving protocol is to be executed when a user wants to produce the latest master copies of all the shared notes for the session, and the session leaving protocol is to be executed when a user wants to quit from an ongoing session.

Protocol 5.2. Session Creation: a new app creates a new session

1. The app establishes a network connection with the server and sends a request $\langle CREATE \rangle$ to the server.
2. When the server receives the request from the app, it performs the following session creation process:
   (a) assign a session id sid ($1 \leq sid \leq$ m), a Note id nid ($1 \leq nid \leq 4$) within the session, and an app id aid_nid ($1 \leq aid\_nid \leq$ n) for the app that owns Note nid;
   (b) create session sid that contains Note nid, including the master copy of the Note MN, the master incoming buffer MIB, and the sever-side incoming buffer SIB_{aid_nid} for app aid_nid ; and
   (c) send a response $\langle CREATE, sid, nid, aid\_nid, MN \rangle$ to the app.
3. When the app receives the response from the server, it first tags itself with the assigned sid, nid, and aid_nid, then creates $OB^{nid}_{aid\_nid}$ and $AIB^{nid}_{aid\_nid}$, and finally opens $RN^{nid}_{aid\_nid} = MN$.

Protocol 5.3. Session Joining: a new app joins session p

1. The app establishes a network connection with the server and sends a request $\langle JOIN, p \rangle$ ($1 \leq$ p $\leq$ m) to the server.
2. When the server receives the request from the app, it performs the following session joining process on session p:

(a) lock session p, including all the existing Notes, e.g., Note i owned by app aid_i and Note j owned by app aid_j ($1 \leq \mathrm{i} \neq \mathrm{j} \leq 4$ and $1 \leq aid\_i \neq aid\_j \leq \mathrm{n}$);

(b) assign a Note id nid ($1 \leq nid \leq 4$ and $nid \neq \mathrm{i} \neq \mathrm{j}$) and an app id aid_nid ($1 \leq aid\_nid \leq \mathrm{n}$ and $aid\_nid \neq aid\_i \neq aid\_j$).

(c) create Note nid, including MN, MIB, and SIB_{aid_i}, SIB_{aid_j}, and SIB_{aid_nid}.

(d) within Notes i and j, create SIB_{aid_nid} and then execute and remove all operations in MIB to produce the latest MN;

(e) send a response $\langle JOIN, nid, aid\_nid, MN, i, note\ i\text{'s } MN, j, note\ j\text{'s } MN\rangle$ to the app and a response $\langle JOIN, nid, aid\_nid, MN\rangle$ to apps aid_i and aid_j and; and

(f) unlock session p.

3. When the app receives the response from the server, it first tags itself with p, nid, and aid_nid, then creates $OB^i_{aid\_i}$ and $AIB^i_{aid\_i}$, $OB^j_{aid\_j}$ and $AIB^j_{aid\_j}$, $OB^{nid}_{aid\_nid}$ and $AIB^{nid}_{aid\_nid}$, and finally opens $RN^{nid}_{aid\_nid} = note\ nid\text{'s } MN$, $RN^i_{aid\_nid} = note\ i\text{'s } MN$, and $RN^j_{aid\_nid} = note\ j\text{'s } MN$.

4. When app aid_i (or aid_j) receives the response from the server, it creates $OB^{nid}_{aid\_i}$ (or $OB^{nid}_{aid\_j}$) and $AIB^{nid}_{aid\_i}$ (or $AIB^{nid}_{aid\_j}$), and then opens $RN^{nid}_{aid\_i}$ (or $RN^{nid}_{aid\_j}$) = $note\ nid\text{'s } MN$.

Protocol 5.4. Session Saving: app aid saves session p

1. App aid executes the operation broadcast protocol for each non-empty OB.

2. App aid establishes a network connection with the server and sends a request $\langle SAVE, p\rangle$ to the server.

3. When the server receives the request from app aid, it performs the following session saving process on session p:

(a) lock session p, including all the existing Notes;

(b) execute and remove all operations in each Note's MIB to produce the latest master copy MN;

(c) send a dummy response $\langle SAVE\rangle$ to the app; and

(d) unlock session p.

4. When the app receives the response from the server, it takes no action.

Protocol 5.5. Session Leaving: app aid leaves session p

1. App aid locks the local replicas of all the shared Notes.

2. App *aid* executes the operation broadcast protocol for each non-empty OB.

3. App *aid* establishes a network connection with the server and sends a request $\langle LEAVE, aid, p\rangle$ to the server.

4. When the server receives the request from the app, it performs the following session leaving process on session p:

   (a) lock session p, including all the existing Note;

   (b) execute all operations in the *MIB* from Note *nid* owned by app *aid* to produce the latest master copy MN;

   (c) back up MN on the server and then remove app *aid*'s Note *nid* from session p;

   (d) remove app *aid* from other Note in session p, including SIB_{aid} in each of these notes;

   (e) send a dummy response $\langle LEAVE\rangle$ to the app and a response $\langle LEAVE, aid, nid\rangle$ to other apps in session p, and

   (f) unlock session p.

5. When the app receives the response from the server, it quits. When other apps, e.g., App k, receive the response from the server, they remove OB_k^{nid} and AIB_k^{nid} and RN_k^{nid} from the interface.

Chapter 6

Tests and Results

6.1 Hypotheses

To test our ideas, we designed experiments to determine whether increasing engagement from a student-to-student perspective is a viable solution without requiring the lecturer to change their pedagogy, and to verify that the peer interaction does not disrupt either the lecturer or any other students in the venue, including within the same group. We video-recorded four separate lectures on a topic with the intention of producing the type of non-interactive lecture that causes students to not engage (Hitchens and Lister, 2009) for the purpose of testing three hypotheses:

$\mathbf{H}_1$: students are more engaged in the lecture with collaborative than with individual note-taking,

$\mathbf{H}_2$: students are more satisfied with sharing spatially separated workspaces than with sharing a common workspace, and

$\mathbf{H}_3$: students are more engaged outside the lecture with collaborative than with individual note-taking.

Hypothesis H_2 is decoupled to six sub-hypotheses, including:

$\mathbf{H}_{21}$: sharing spatially separated workspaces keeps students more engaged than sharing a common workspace,

$\mathbf{H}_{22}$: sharing spatially separated workspaces is a better implementation of the *Seven Principles* than sharing a common workspace,

$\mathbf{H}_{23}$: sharing spatially separated workspaces is more helpful than sharing a common workspace,

$\mathbf{H}_{24}$: sharing spatially separated workspaces is less distracting than sharing a common workspace,

$\mathbf{H}_{25}$: sharing spatially separated workspaces is more beneficial than sharing a common workspace, and

$\mathbf{H}_{26}$: sharing spatially separated workspaces is more likely to persuade students to come to non-interactive lectures than sharing a common workspace.

Hypothesis H_3 is decoupled to three sub-hypotheses, which are:

$\mathbf{H}_{31}$: more students prepare for the lecture beforehand with collaborative than with individual note-taking,

$\mathbf{H}_{32}$: more students revise notes after the lecture with collaborative than with individual note-taking, and

$\mathbf{H}_{33}$: more students discuss notes with at least one other person after the lecture with collaborative than with individual note-taking.

6.2 Methodology

Four peer interaction methods $M_1 - M_4$ were tested with M_1 not allowing peer interaction, M_2 and M_3 supporting peer interaction through a shared common workspace, and M_4 supporting peer interaction through multiple shared, spatially separated, virtual workspaces.

$\mathbf{M}_1$: no peer interaction.

$\mathbf{M}_2$: audible peer interaction with a shared, common, tangible workspace, where the note-taking occurred on large sheets of paper with each member using a different coloured marker pen.

$\mathbf{M}_3$: silent peer interaction with a shared, common, virtual workspace provided by *Google Docs* on Nexus 7 tablets, where members of a group took notes in the same document and everyone was exposed to all members' notes and permitted to edit anywhere in the common workspace.

$\mathbf{M}_4$: silent peer interaction with multiple shared, spatially separated, individual virtual workspaces provided by *GroupNotes* on Nexus 7 tablets, where each member had their own workspaces with the option to hide, view, and edit all other workspaces according to their own requirements and without forcing that view on other members in the group.

A total of 32 university students across multiple disciplines participated in four testing sessions T_1 to T_4, where the four methods were tested respectively in the order from M_1 to M_4. The students mainly arrived as pre-organised groups of 2, 3 or 4 with only 6 of the 32 participants asking to be placed into a suitable group. The testing was not part of any enrolled class workload of the students. Each group performed all tests isolated from any other group to ensure a uniform environment and all groups were tested in the same order from T_1 to T_4.

We distributed a pre-questionnaire to students before conducting the four test sessions in order to capture some demographic details as well as data related to attitudes toward attending lectures and the learning methods used in lectures. We also arranged a post-questionnaire after the four tests to revisit the questions related to their attitude towards attending and engaging with the lecture content before, during and after the actual lecture, assuming the availability of a commercial grade *GroupNotes*. The four testing sessions each consisted of the participants viewing a pre-recorded lecture (one for each test) and then completing a questionnaire to capture their opinions on how well that particular method adhered to principles $P_2 - P_7$, as well as how engaged this level of adherence made them feel. Following the questionnaire was a quiz examining the lecture content whose main purpose was to persuade participants to treat the exercise seriously. An additional purpose to the quiz in the long term is to assist with the design of tests that would measure the effectiveness of individual learning outcomes should the effectiveness of *GroupNotes* in engaging students prove to be significant.

Figure 6.1: A Shared Common Tangible Workspace

M_1 was designed to set a baseline for each individual student regarding their normal work practice when attending a non-interactive lecture, while $M_2 - M_4$ introduced groups and allowed interaction between members, with the interaction method being the independent variable in the three experiments.

M_2, as shown in Figure 6.1, allowed peer interaction through a shared, common, tangible workspace, where the note-taking occurred on large sheets of paper ($102cm \times 76cm$) with each member using a different coloured marker pen and audible communication among the members permitted. We recognise this is not a viable option for lectures as the noise level would be too distracting and the desk space for a communal note area would require a redesign of lecture venues. This method introduced participants to the familiar social interaction in the unfamiliar setting of a lecture using our most natural method of interaction, our voice, as well as introducing the communal note area. This method was also where participants were encouraged to develop some strategies that allowed them to maximise the groups and their own aims, regarding the type of note coverage they and the group wanted.

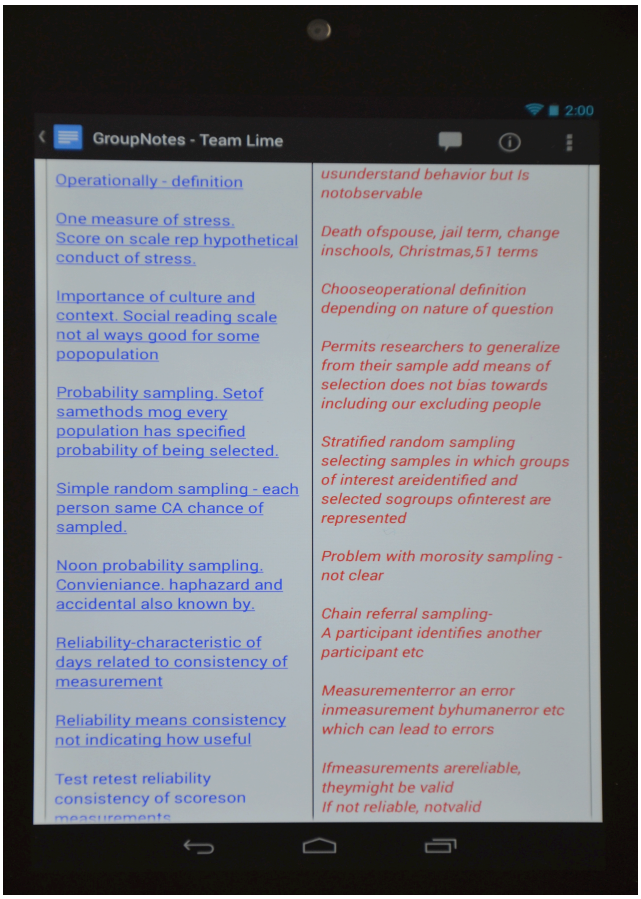

Figure 6.2: A Shared Common Virtual Workspace

M_3 introduced mobile devices to the testing and allowed peer interaction through a common virtual workspace shared across Nexus 7 tablets (one for each group member), as shown in Figure 6.2. Again, the participants watched a pre-recorded lecture and took notes according to what was most beneficial to the group while attempting to minimise any negative impact on their own performance. The major difference here is that audible communication was prohibited, requiring all communication, including coordination, to occur in writing, making it a viable solution for a lecture environment.

The tablets were set up with a template in *Google Docs*, as shown in Figure 6.2, allowing members of a group to take notes in the same document, where everyone was exposed to all members' notes and permitted to edit anywhere in the shared workspace.

Figure 6.3: Multiple Shared Spatially Separated Virtual Workspaces

M_4 differed from M_3 in that peer interaction was facilitated through multiple shared spatially separated individual virtual workspaces provided by *GroupNotes* as shown in Figure 6.3 rather than a common workspace as provided by *Google Docs*. Each individual member had their own workspace with the option to view or edit all other workspaces according to their own requirements and without forcing that view on others in the group. It not only eliminated the distraction brought by others' note-taking activities but also offered the much needed flexibility for each individual to determine their own view of the content at any time without affecting any other group member's view.

All groups performed tests in the order from T_1 to T_4, where a distinct set of variables were manipulated. T_1 involved no collaboration (M_1) while the remaining three tests did. T_2 and T_3 involved the use of common shared workspaces with T_2 having both audible and a shared tangible workspace (M_2), meaning there was no escaping from the input of others. T_3 removed the audible input from the testing

but still provided a common shared workspace virtually (M_3) on a mobile device. T_4 removed the common shared workspace, both audible and text-based, replacing them with multiple, virtual, spatially separated workspaces (M_4) which can be shared but did not force the immediate viewing of input from other group members.

6.3 Results

6.3.1 Preferred Note-taking Method

Table 6.1 ($N = 32$) shows the choice of participants' preferred note-taking method after each of the four tests.

Table 6.1: Choice of Preferred Note-taking Method after Each Test

Preferred Method	After T_1	After T_2	After T_3	After T_4
M_1	-	14	7	5
M_2	-	18	6	3
M_3	-	-	19	0
M_4	-	-	-	24

Figures 6.4(a) - (c) depict the choice of preferred method between collaborative and individual note-taking after each test. In particular, 18 (or 56.2%), 25 (or 78.1%), and 27 (or 84.4%) chose collaborative note-taking as their preferred method, while 14 (or 43.8%), 7 (or 21.9%), and 5 (or 15.6%) still preferred individual note-taking, after T_2, T_3, and T_4 respectively. Figures 6.4(d) - (e) further illustrate that among those who chose collaborative note-taking, 19 (or 76%) and 24 (or 88.9%) preferred the quiet & virtual approach, while 6 (or 24%) and 3 (or 11.1%) liked the audible & tangible approach, after T_3 and T_4 respectively. With the introduction of M_4 in T_4, Figure 6.4(f) shows that 24 (or 88.9%) preferred sharing spatially separated workspaces and only 3 (or 11.1%) stayed with their choice of sharing a common workspace. It is very encouraging to notice from Figure 6.4(g) that although it is only a proof-of-concept application, all participants preferred the spatially separated workspaces of *GroupNotes* to the shared common workspace supported by *Google Docs*.

Method M_2 allowed talking and provided a shared tangible workspace. In reality, this is not a viable option within an ongoing lecture, which may account for the relatively high numbers of students choosing to select M_1 as their preferred method after T_2 (Figure 6.4(a)). However, the introduction of methods M_3 and M_4 as more viable options opened their horizons to what is increasingly possible and therefore allowed them to meaningfully assess the options after T_3 and T_4. The results suggest that: (a) students prefer collaborative to individual note-taking, (b) students prefer sharing virtual workspaces in a quiet environment to tangible workspaces in an audible environ-

ment, and (c) students prefer sharing spatially separated workspaces to a constrained common workspace.

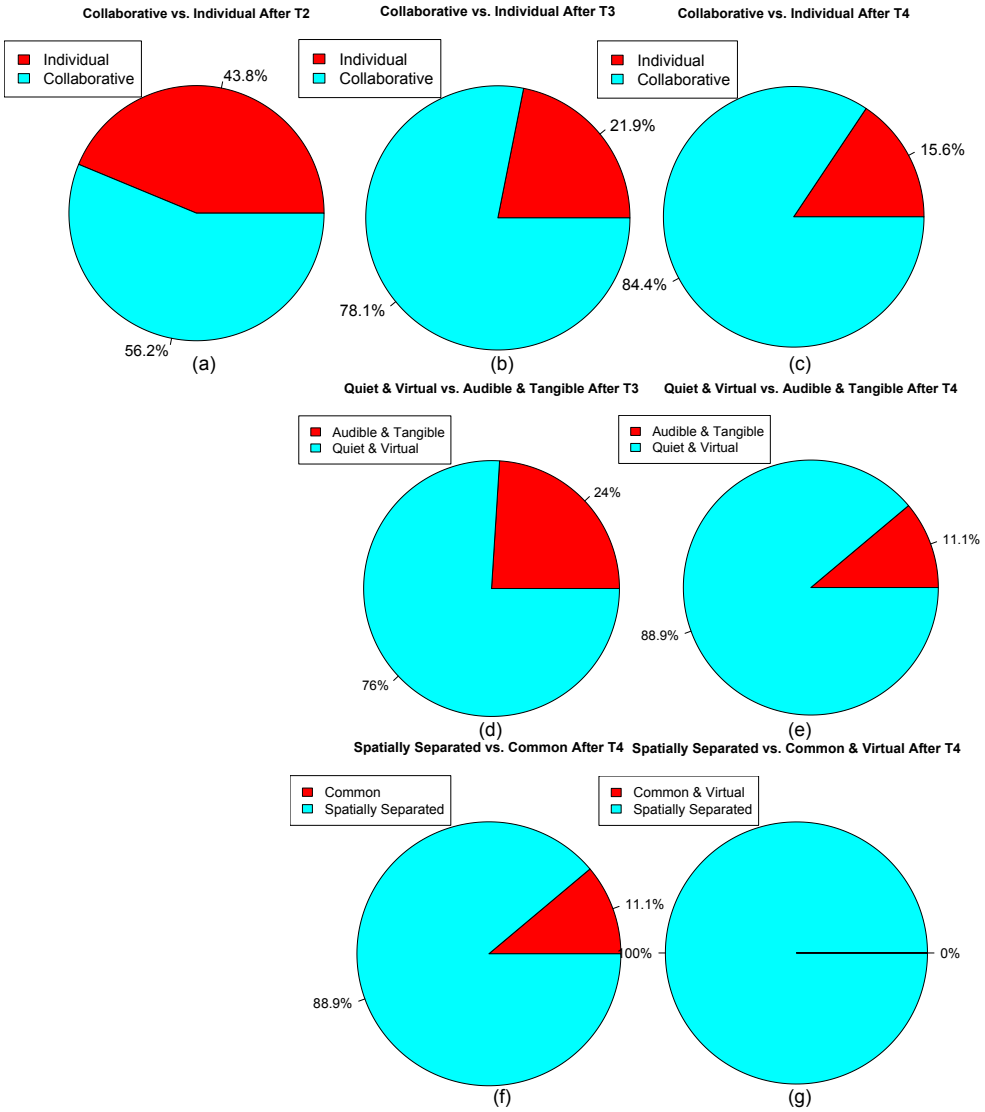

Figure 6.4: Distribution of Preferred Note-taking Methods

6.3.2 Engagement in the Lecture

Table 6.2 provides the test results of participants' self-assessed engagement from the questionnaires after M_1 (Mean = 2.63, SD = 0.87), after M_2 & M_3 combined (Mean = 3.40, SD = 0.99), and after M_4 (Mean = 4.03, SD = 0.71) using a 5-point Likert scale. T-test results indicated that hypotheses H_1 and H_{21} were confirmed at $p < 0.05$, that is, students are more engaged with collaborative than with individual note-taking, and with sharing spatially separated workspaces than with sharing a common workspace.

Table 6.2: Engagement in the Lecture: Collaborative vs. Individual and Sharing of Spatially Separated Workspaces vs. a Common Workspace

p-value	Questionnaire	Mean	Std Dev
0.0001	M_1	2.63	0.87
	M_4	4.03	0.71
0.0002	M_2 & M_3 combined	3.40	0.99
	M_4	4.03	0.71

6.3.3 Student Satisfaction

For H_{22}, 16 questions were asked to gather students' opinions on the implementation of the *Seven Principles* using a 5-point Likert agreement scale, where 4 questions were related to P_2 and 2 questions were related to each of the principles P_3 - P_7, which are:

$\boldsymbol{P_{2.1}}$: *"working within a group during the lecture develops my capacity for the sharing of knowledge to the mutual benefit of the members of that group"*,

$\boldsymbol{P_{2.2}}$: *"the reciprocal benefit of sharing knowledge within our group increases my engagement with the lecture content"*,

$\boldsymbol{P_{2.3}}$: *"working within a group during a lecture promotes cooperation in order to achieve greater individual knowledge capture"*,

$\boldsymbol{P_{2.4}}$: *"cooperating with other group members during a lecture to increase knowledge capture increases my engagement with the lecture"*,

$\boldsymbol{P_{3.1}}$: *"working within a group during the lecture promotes active learning through the examples provided by myself and other group members to illustrate the understanding of new or existing knowledge and also, the application of that knowledge"*,

$\boldsymbol{P_{3.2}}$: *"my engagement with the lecture is enhanced through the examples I use to illustrate my new or existing knowledge, knowing that it is to be accessed by others in my group to assist in confirming existing, or creating their own new knowledge"*,

$\boldsymbol{P_{4.1}}$: *"working within my group during the lecture delivers prompt feedback because I am able to quickly validate or challenge my new/existing knowledge at the appropriate teaching moment through being able to access the knowledge of the other group members"*,

$\boldsymbol{P_{4.2}}$: *"my engagement during the lecture is enhanced due to the prompt feedback I am able to access from the work of my group members"*,

$\boldsymbol{P_{5.1}}$: *"working within my group during the lecture emphasises time on task as the shared goal is greater knowledge capture, which requires commitment. The awareness that others will be able to see any reduction in note output such as would occur if I*

checked out a Facebook page, sent an SMS, fell asleep etc. provides the motivation to remain on task",

$\boldsymbol{P_{5.2}}$: *"my engagement with the lecture is enhanced because I am motivated to remain on task in order that I meet the expectations of my group members"*,

$\boldsymbol{P_{6.1}}$: *"working within my group encourages me to meet the agreed expectations of the group in terms of meeting our shared goal of increasing the knowledge capture during the lecture"*,

$\boldsymbol{P_{6.2}}$: *"my engagement with the lecture is enhanced through a joint commitment with my other group members to meet an expected standard"*,

$\boldsymbol{P_{7.1}}$: *"working within a group exposes me to the different talents and ways of learning of others in my group. As I know they have the same commitment to our shared goal my respect for these different methods of knowledge capture is increased"*, and

$\boldsymbol{P_{7.2}}$: *"my engagement with the lecture in enhanced when I am working with others who share the same goal as I and also expose me to different talents and ways of learning which provide a different perspective to my own"*.

Figure 6.5 shows that sharing of spatially separated workspace in M_4 is generally perceived as a better implementation of the *Seven Principles* than only sharing a common workspace in M_2 or M_3. All T-test results except $P_{2.3}$, $P_{5.1}$, $P_{6.2}$, and $P_{7.1}$ were statistically significant at $p < 0.05$.

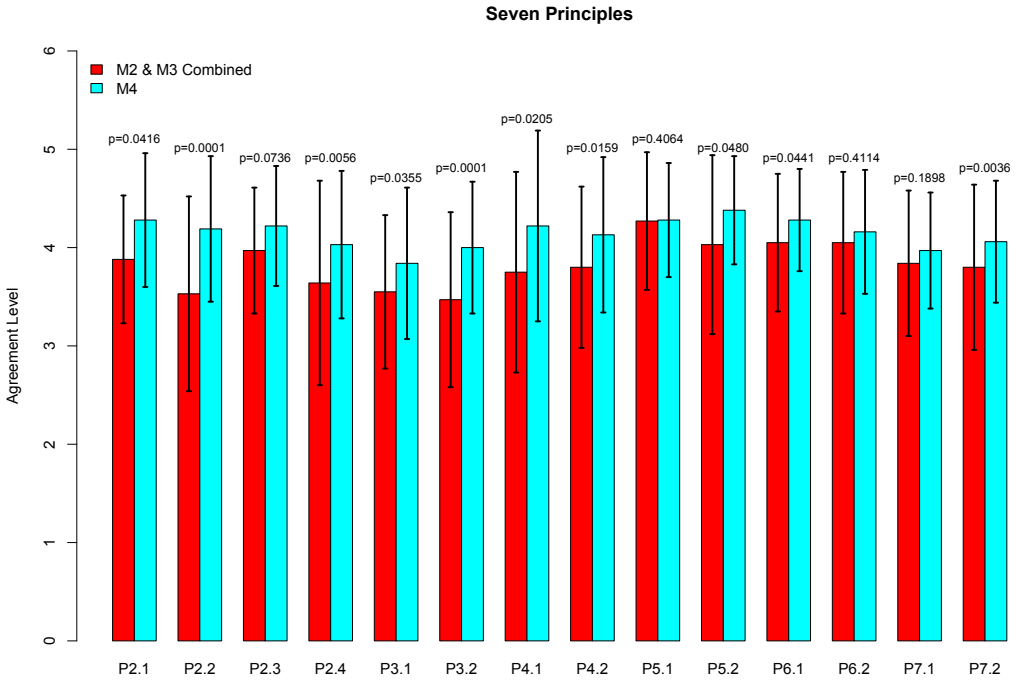

Figure 6.5: Implementation of the Seven Principles: Sharing of Spatially Separated Workspaces vs. a Common Workspace

For H_{23} - H_{26}, 5 questions were asked to gather students' satisfaction with the way collaborative note-taking is supported using a 5-point Likert agreement scale, which are:

Helpful: *"access to the work of my group members during the lecture using this method was helpful"*,

Distracting: *"access to the work of my group members during the lecture using this method was distracting"*,

Beneficial.1: *"access to the work of my group members during the lecture using this method provided a greater benefit than working alone"*,

Beneficial.2: *"the benefit from access to the work of my group members during the lecture using this method more than compensated for the level of distraction, if any, it caused me"*, and

Attending: *"if cooperation supported by this method were permitted during non-interactive lectures, I would attend this lecture"*.

Figure 6.6 shows that students are more satisfied with sharing spatially separated workspaces in M_4 than only sharing a common workspace in M_2 or M_3. In particular, (a) access to the work of group members through sharing spatially separated workspaces is more helpful than sharing a common workspace ($p = 0.0079$), (b) access to the work of group members through sharing spatially separated workspaces is less distracting than sharing a common workspace ($p = 0.0001$), (c) access to the work of group members through sharing spatially separated workspaces provides a greater benefit than sharing a common workspace ($p = 0.0004$ and $p = 0.0001$), and (d) students are more likely to be persuaded to come to non-interactive lectures with the support of sharing spatially separated workspaces than sharing a common workspace ($p = 0.0013$).

6.3.4 Engagement outside the Lecture

For H_{31} - H_{33}, 3 questions (one for each hypothesis) were distributed to participants both in the pre-questionnaire and post-questionnaire in order to capture and compare their attitudes to the engagement with topic material outside the lectures, when considering collaborative and individual note-taking methods. Table 6.3 shows the results, where H_{32} and H_{33} are positively confirmed ($p = 0.0001$). That is, more students would choose to revise notes and discuss notes with at least one other person after the lecture with the support of collaborative note-taking than individual note-taking. However, H_{31}, that is more students would prepare for the lecture beforehand with collaborative than individual note-taking, was not confirmed at the $p < 0.05$ level.

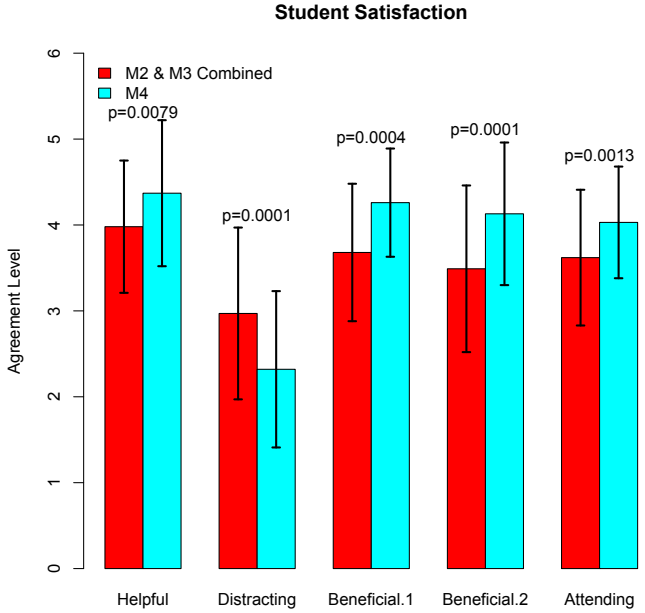

Figure 6.6: Student Satisfaction: Sharing of Spatially Separated Workspaces vs. a Common Workspace

Table 6.3: Engagement outside the Lecture: Collaborative vs. Individual Note-taking

p-value	Questionnaire	Mean	Std Dev
0.06	Pre: H_{31}	2.59	0.95
	Post: H_{31}	3.06	1.01
0.0001	Pre: H_{32}	2.81	1.36
	Post: H_{32}	3.84	0.81
0.0001	Pre: H_{33}	1.88	1.13
	Post: H_{33}	3.16	0.94

The results from the post-questionnaire also revealed the key features of *GroupNotes* that make social interaction during a lecture viable and that make M_4 distinct from M_3. Of 32 responses,

> 29 (or 90.6%) quoted the novel multi-user interface supporting spatially separated workspaces,
> 28 (or 87.5%) quoted the real-time access to other group member's notes, and
> 25 (or 78.1%) quoted the flexibility of the user interface and the ability to minimise distraction.

The real-time availability of all content generated by group members but accessible in different workspaces according to the needs and abilities of the individual allows for the cooperation and/or collaboration of the group members to provide a benefit over working alone.

6.4 Discussion

This research set out to investigate three hypotheses of which two were confirmed and the third partially confirmed. For hypothesis $\mathbf{H}_1$, 27 of the 32 participants indicated collaborative over individual note-taking as their preferred option. Three participants chose method $\mathbf{M}_2$, where audible conversation was permitted and therefore not a viable option, however even without these students there were still 75% in favour of collaboration.

Hypothesis $\mathbf{H}_2$ is confirmed with students reporting more satisfaction sharing spatially separated workspaces than with a common one. Of the six sub-hypotheses only $\mathbf{H}_{22}$, spatially separated workspaces being a better implementation of the *Seven Principles* than a common workspace did not provide statistically significant results for each of the fourteen question asked. Four questions only relating to the *Seven Principles*, $P_{2.3}$, $P_{5.1}$, $P_{6.2}$, and $P_{7.1}$, while still in favour of spatial separation, did not meet the required level of significance.

Hypothesis $\mathbf{H}_3$ regarding engagement outside of the lecture was only partially confirmed. $\mathbf{H}_{32}$ and $\mathbf{H}_{33}$ are both confirmed with students indicating they would revise the notes generated by the group and discuss them with at least one other person however $\mathbf{H}_{31}$ was not confirmed. More students would prepare for the lecture beforehand when part of a collaborative group than as an individual was not confirmed ($p = 0.06$). This result did surprise me as I felt that being part of the group would encourage the student to do the best they could for their group members in all circumstances. The short term nature of this testing, combined with no real world implications if the knowledge was not acquired as it was not for actual grades may not accurately portray what would occur outside a testing environment. It would be interesting to revisit this question after the implementation of *GroupNotes* in a real lecture setting over the course of a semester and see if peer pressure from within the group, or the individual student's own sense of professionalism, would increase the percentage of students motivated to pre-prepare for lectures.

These experiments are limited by an artificial environment. each group performed the tests in isolation in a small tutorial room where external distractions were kept to a minimum. The learning outcomes were beyond the scope of the research with the testing phase of the lecture content included to add to the realism of the exercise so the participants may not have tried as hard as if the content was assessable and contributed to their grade.

In terms of student engagement with lecture content, both during and external to the actual lecture session, these results provide confidence that a student centred approach is feasible and that further testing in a real-world situation is warranted.

Chapter 7

Future Work

It is envisaged that the future direction of this research will progress in two separate areas. Firstly, it is in identifying if there are any particular student group, or lecture types, where a solution like *GroupNotes* is particularly suited. The second area is in aiding the lecturer in gaining an appreciation of what the students are understanding from the lecture.

7.1 Students

From the perspective of students there is more research to be done in regard to where a solution, such as *GroupNotes*, is most effective and to determine where it is does not provide a sufficient benefit to continue its use. The other area to investigate is the possibility that the solution can play a part in student retention.

There is a great deal more that can be investigated with respect to the optimal use of a tool such as *GroupNotes*. What is the ideal student lecture situation – is it useful in a maths lecture where all content is dynamically generated in real-time or does it work best for a session where partial notes are provided? Does *GroupNotes* work equally well for foreign language students as for English speakers? Can a solution such as *GroupNotes* be introduced into a fully interactive lecture, or flipped classroom, where discussion is expected? Are there any additional features students would like to see incorporated?

The second area related to students is in investigating the social aspect of the solution as a way in which to increase the retention of students within the university as a whole. A feeling of isolation is a major contributor to students abandoning their study and a solution that uses a group structure and is useful in increasing the engagement of students in the lecture content, both during and external to the lecture session, may assist. At present the groups self select, meaning some prior knowledge of the other group members. For many students, particularly those who are feeling isolated,

and are therefore more likely to abandon their studies, this prior knowledge is not available. Research into effective means of identifying compatible group members to team up with would provide a structured approach for new students to establish working arrangements, and perhaps friendships, with the added incentive of using a solution that encourages their engagement in the lecture content and in educationally meaningful activities. If the student is no longer feeling isolated there is a higher probability they will continue their studies.

7.2 Lecturer

There are two areas of interest to further develop *GroupNotes* for the lecturer. The features that could be integrated into the application for real-time access by the lecturer, and the information that will become available post-lecture.

The features that are available to the lecturer may or may not involve two-way interaction or real-time access by the lecturer. An example of a feature that could be implemented is voting buttons for the student. When the lecturer asks 'does everyone get this?' and all students in the lecture nod in the affirmative (publicly) the results available to the lecturer – (privately) may tell a different story. Below a certain threshold the lecturer may choose to go over the content again to ensure that there is an adequate understanding by the students. These same buttons could also be used interactively during the session by both the lecturer and the student. Multiple choice, true/false, and short answer questions can be assigned to the students and marked immediately. The results of these questions can then inform the lecturer where further elaboration is needed. Questions can be sent directly to the lecturer for a response, as can any comments the students wish to make e.g., 'you are going too fast', or 'Slide 4 does not make sense'. These same answers and comments may not be viewed in real-time by the lecturer but may be reviewed after the session and form the basis for additional information sources to be provided, or additional exercises set.

In addition to the information that may have been accessed in real-time there is the information contained in tens, and perhaps hundreds of sets of notes taken by students for a particular lecture that is now available to the lecturer. These are in a digital format that can be analysed. Questions can be asked such as 'What content is being understood and what is being missed'? and 'Is the level of information provided appropriate for the existing knowledge of the students or is it too advanced'?. A review of the notes from a lecture may provide an insight to the lecturer regarding where they were losing the attention of their students and lead to a change in approach. An early morning lecture may mean that the critical information is left until the second half of the lecture whereas lectures after the lunch break may require that this information is provided first. Knowing that your group starts to lose focus around the 20 minute mark can allow the scheduling of a short break to allow a drink or review of the content

covered with a peer. It may also be time for a change-up, such as a quick video or a Think/Pair/Share session. The post-lecture review of the notes may also identify where additional instruction or information may be required. If the majority of the notes available indicate that a critical piece of information has not been adequately understood the opportunity to advise students of this is available. An email identifying that a certain aspect of the knowledge expected to have been gained from the lecture appears to have been missed then the provision of additional sources of information in the form of documents or links to further information can be provided.

Further investigation into features the lecturers would like integrated into *GroupNotes* is also required.

Bibliography

Aagard, H. P., Bowen, K. D. and Olesova, L. A. (2010), 'Hotseat: Opening the backchannel in large lectures'.

Adelaide University (2015), 'University of Adelaide Graduate Attributes'. Online; accessed 28-July-2015.
URL: *https://www.adelaide.edu.au/learning/strategy/gradattributes/*

Ajzen, I. (1991), 'The theory of planned behavior', *Organizational Behavior and Human Decision Processes* **50**, 33.

Anderson, L. W. and Krathwohl, D. R. (2001), *A taxonomy for learning, teaching, and assessing: A revision of Bloom's taxonomy of educational objectives*, Longman, New York.

Anderson, R., Anderson, R., Simon, B., Wolfman, S. A., VanDeGrift, T. and Yasuhara, K. (2004), Experiences with a tablet pc based lecture presentation system in computer science courses, *in* 'ACM SIGCSE Bulletin', Vol. 36, ACM, pp. 56–60.

Bailey, N., Hagan, C., Hagan, D., Franke, K. and Sanson, G. (2011), Innovation with confidence: Testing monash metl, a collaborative educational tool, *in* 'Global Learn', Vol. 2011, pp. 17–26.

Begole, J., Rosson, M. B. and Shaffer, C. A. (1999), 'Flexible collaboration transparency: supporting worker independence in replicated application-sharing systems', *ACM Transactions on Computer-Human Interaction* **6**(2), 95–132.

Bernstein, P., Goodman, N. and Hadzilacos, V. (1987), *Concurrency control and recorvery in database systems*, Addision-Welsley.

Bier, E. A. and Freeman, S. (1991), Mmm: a user interface architecture for shared editors on a single screen, *in* 'Proceedings of the 4th annual ACM symposium on User interface software and technology', pp. 79–86.

Biggs, J. B. (1999), *Teaching for Quality Learning at University*, Open University Press, Buckingham.

Bligh, D. A. (2000), *What's The Use of Lectures?*, Jossey-Bass, San Francisco, CA.

Bloom, B. S., Engelhart, M. D., Furst, E. J., Hill, W. H. and Krathwohl, D. R. (1956), *Taxonomy of educational objectives: The classification of educational goals. Handbook I: Cognitive domain.*, David McKay Company, New York.

Boch, F. and Piolat, A. (2005), 'Note taking and learning a summary of research'.

Bock, G.-W., Zmud, R. W., Kim, Y.-G. and Lee, J.-N. (2005), 'Behavioral intention formation in knowledge sharing: Examining the roles of extrinsic motivators, social-psychological forces, and organizational climate', *MIS Quarterly* **29**(1), pp. 87–111.
URL: *http://www.jstor.org/stable/25148669*

Boyd, R. D., Apps, J. W. et al. (1980), *Redefining the discipline of adult education*, Jossey-Bass San Francisco, CA.

Bransford, J. D., Brown, A. L. and Cocking, R. R. (2000), *How People Learn : Brain, Mind, Experience and School (Expanded Edition)*, National Academies Press.

Cheong, C., Bruno, V. and Cheong, F. (2012), 'Designing a mobile-app-based collaborative learning system', *Journal of Information Technology Education* **11**.

Chickering, A. W. and Gamson, Z. F. (1991), 'Seven principles for good practice in undergraduate education', *New directions for teaching and learning* **1991**(47), 63–69.

Codoxware Pte Ltd (2014), 'Seamless real-time collaboration in microsoft office'. Online; accessed 30-July-2015.
URL: *http://www.codoxware.com/*

Cole, M., V., J.-S., Scribner, S. and Souberman, E. E. (1978), *Mind in society: The development of higher psychological processes*, Harvard University Press, Cambridge, Mass.

Constant, D., Kiesler, S. and Sproull, L. (1994), 'What's mine is ours, or is it? a study of attitudes about information sharing', *Information systems research* **5**(4), 400–421.

Costa, J. C. E., Ojala., T. and Korhonen., J. (2008), Mobile lecture interaction: Making technology and learning click, *in* I. A. Snchez and P. Isaas, eds, 'IADIS International Conference Mobile Learning', pp. 119–124.

Crouch, C. and Mazur, E. (2001), 'Peer instruction: Ten years of experience and results', *American journal of physics* **69**(9), 8.

Davis, F. D. (1989), 'Perceived usefulness, perceived ease of use, and user acceptance of information technology', *MIS quarterly* **13**, 319–340.

Davis, K. M., Kelly, M., Malani, R., Griswold, W. G. and Simon, B. (2007), Preliminary evaluation of noteblogger: Public note-taking in the classroom, *in* 'Workshop on the Impact of Pen-based Technology on Education'.

Davis, R. D., Landay, J. A., Chen, V., Huang, J., Lee, R. B., Li, F. C., Lin, J., Morrey III, J. B., Schleimer, B., Price, M. N. and Schilit, B. N. (1999), Notepals: lightweight note sharing by the group, for the group, *in* 'Proceedings of the SIGCHI Conference on Human Factors in Computing Systems', CHI '99, ACM, New York, NY, USA, pp. 338–345.
URL: *http://doi.acm.org/10.1145/302979.303107*

De Corte, E. (1995), 'Fostering cognitive growth: A perspective from research on mathematics learning and instruction', *Educational Psychologist* **30**(1), 37–46.
URL: *http://dx.doi.org/10.1207/s15326985ep3001_4*

Deci, E. and Ryan, R. (1985), *Intrinsic Motivation and Self-Determination in Human Behavior*, Perspectives in Social Psychology, Springer.

Dunkel, P. (1988), 'The content of l1 and l2 students' lecture notes and its relation to test performance', *TESOL Quarterly* **22**(2), 259–281.

Dunkel, P. and Davy, S. (1989), 'The heuristic of lecture notetaking: Perceptions of american & international students regarding the value & practice of notetaking', *English for Specific Purposes* **8**(1), 33–50.

Ellis, C. A., Gibbs, S. J. and Rein, G. (1991), 'Groupware: Some issues and experiences', *Communications of the ACM* **34**(1), 39–58.
URL: *http://doi.acm.org/10.1145/99977.99987*

Evernote Corporation (2015), 'Penultimate: Beautiful digital handwriting'. Online; accessed 12-September-2015.
URL: *https://evernote.com/penultimate/*

Fishbein, M. and Ajzen, I. (1975), *Belief, Attitude, Intention, and Behavior: An Introduction to Theory and Research.*, Addison-Wesley., Reading, MA.

Flinders University (2015), 'Graduate qualities'. Online; accessed 28-July-2015.
URL: *http://www.flinders.edu.au/graduate-qualities/*

Ginger (2015), 'Notability: Fall in love with note taking'. Online; accessed 12-September-2015.
URL: *http://www.gingerlabs.com/*

Google (2014), 'With google docs, you can write, edit, and collaborate wherever you are. for free.'. Online; accessed 30-July-2015.
URL: *https://www.google.com.au/docs/about/*

Google (2015), 'Google keyboard'. Online; accessed 12-September-2015.
URL: *https://play.google.com/*

Greenberg, S., Gutwin, C. and Cockburn, A. (1996), Awareness through fisheye views in relaxed-wysiwis groupware, *in* 'Proceedings of the Conference on Graphics Interface '96', GI '96, Canadian Information Processing Society, Toronto, Canada, pp. 28–38.
URL: *http://dl.acm.org/citation.cfm?id=241020.241032*

Greenberg, S. and Marwood, D. (1994), Real time groupware as a distributed system: concurrency control and its effect on the interface, *in* 'Proceedings of the 1994 ACM Conference on Computer Supported Cooperative Work', CSCW '94, ACM, New York, NY, USA, pp. 207–217.
URL: *http://doi.acm.org/10.1145/192844.193011*

Hartley, J. and Davies, I. K. (1978), 'Note-taking: A critical review', *Innovations in Education & Training International* **15**(3), 207–224.
URL: *http://dx.doi.org/10.1080/0033039780150305*

Hitchens, M. and Lister, R. (2009), A focus group study of student attitudes to lectures, *in* 'Proceedings of the Eleventh Australasian Conference on Computing Education - Volume 95', ACE '09, Australian Computer Society, Inc., Darlinghurst, Australia, Australia, pp. 93–100.
URL: *http://dl.acm.org/citation.cfm?id=1862712.1862728*

INKredible (2015), 'Inkredible: Just like paper, but better'. Online; accessed 12-September-2015.
URL: *http://inkredibleapp.com/*

Innovation, S. (2015), 'Squid: Take handwritten notes naturally'. Online; accessed 12-September-2015.
URL: *http://squidnotes.com/*

Järvelä, S., Näykki, P., Laru, J. and Luokkanen, T. (2007), 'Structuring and regulating collaborative learning in higher education with wireless networks and mobile tools', *Journal of educational technology & society* **10**(4), 71–79.

Kam, M., Wang, J., Iles, A., Tse, E., Chiu, J., Glaser, D., Tarshish, O. and Canny, J. (2005), Livenotes: a system for cooperative and augmented note-taking in lectures, *in* 'Proceedings of the SIGCHI Conference on Human Factors in Computing Systems', CHI '05, ACM, New York, NY, USA, pp. 531–540.
URL: *http://doi.acm.org/10.1145/1054972.1055046*

Karsenty, A. and Beaudouin-Lafon, M. (1993), An algorithm for distributed groupware applications, *in* 'Distributed Computing Systems, 1993., Proceedings the 13th International Conference on', pp. 195–202.

Kiewra, K. A. (1983), 'The process of review: A levels of processing approach', *Contemporary Educational Psychology* **8**(4), 366 – 374.
URL: *http://www.sciencedirect.com/science/article/pii/0361476X83900231*

Kiewra, K. A. (1985*a*), 'Investigating notetaking and review: A depth of processing alternative', *Educational Psychologist* **20**(1), 23–32.
URL: *http://dx.doi.org/10.1207/s15326985ep2001_4*

Kiewra, K. A. (1985*b*), 'Providing the instructor's notes: An effective addition to student notetaking', *Educational Psychologist* **20**(1), 33–39.
URL: *http://dx.doi.org/10.1207/s15326985ep2001_5*

Knister, M. and Prakash, A. (1993), 'Issues in the design of a toolkit for supporting mulitple group editors', *Computing Systems - The Journal of the Usenix Association* **6**(2), 135–166.

Kobayashi, K. (2006), 'Combined effects of notetaking/reviewing on learning and the enhancement through interventions: A metaanalytic review', *Educational Psychology* **26**(3), 459–477.
URL: *http://dx.doi.org/10.1080/01443410500342070*

Koschmann, T. (1999), 'Toward a dialogic theory of learning: Bakhtin's contribution to understanding learning in settings of collaboration'. 115027838.
URL: *http://dl.acm.org/citation.cfm?id=1150240.1150278*

Krathwohl, D. R. (2002), 'A revision of bloom's taxonomy: An overview', *Theory Into Practice* **41**(4), 212–218.
URL: *http://dx.doi.org/10.1207/s15430421tip4104_2*

Kuh, G. D. (2009), 'What student affairs professionals need to know about student engagement', *Journal of College Student Development* **50**(6), 683–706.

Kuh, G. D., Kinzie, J., Buckley, J. A., Bridges, B. K. and Hayek, J. C. (2007), 'Piecing together the student success puzzle: Research, propositions, and recommendations.', *ASHE Higher Education Report* **32**(5), 1–182.
URL: *http://dx.doi.org/10.1002/aehe.3205*

Lenovo (2015), 'Writeit - if you can type it, you can writeit'. Online; accessed 12-September-2015.
URL: *http://www.lenovo.com/us/en/apps/writeit/*

Li, R., Li, D. and Sun, C. (2004), A time interval based consistency control algorithm for interactive groupware applications, *in* 'Parallel and Distributed Systems, 2004. ICPADS 2004. Proceedings. Tenth International Conference on', IEEE Computer Society, pp. 429–436.

Litchfield, A., Raban, R., Dyson, L. E., Leigh, E. and Tyler, J. (2009), Using students' devices and a no-to-low cost online tool to support interactive experiential mlearning, *in* 'Advanced Learning Technologies, 2009. ICALT 2009. Ninth IEEE International Conference on', pp. 674–678.

Lyman, F. (1987), 'Think-pair-share: An expanding teaching technique', *MAA-CIE Cooperative News* **1**(1), 1–2.

Mazur, E. (1997), *Peer Instruction: A User's Manual*, Prentice-Hall, New Jersey.

Munari, A. (1994), 'Profiles of educators, jean piaget, 1896-1980', *Prospects: the quarterly review of comparative education* **24**(1), 17.

Nuance Communications (2010), 'Text input for screens'. Online; accessed 28-July-2015.
URL: *http://www.swype.com*

Patry, M. (2009), 'Clickers in large classes: From student perceptions towards an understanding of best practices', *International Journal for the Scholarship of Teaching and Learning* **3**(2), 1–11.

Perry, B. (2000), 'How the brain learns best', *Instructor; Primary ed* **110**(4), 34.

Radloff, A. (2010), 'Doing more for learning: enhancing engagement and outcomes: Australasian survey of student engagement: Australasian student engagement report.'.

Raynal, M. and Singhal, M. (1996), 'Logical time: capturing causality in distributed systems', *IEEE Computer Magazine* **29**(2), 49–56.

Reilly, M. and Shen, H. (2011), Shared note-taking: a smartphone-based approach to increased student engagement in lectures, *in* 'The 11th International Workshop on Collaborative Editing Systems in Conjunction with ACM Conference on Computer Supported Cooperative Work'.

Sana, F., Weston, T. and Cepeda, N. J. (2013), 'Laptop multitasking hinders classroom learning for both users and nearby peers', *Computers & Education* **62**, 24–31.

Shen, H. and Reilly, M. (2012), 'Personalized multi-user view and content synchronization and retrieval in real-time mobile social software applications', *J. Comput. Syst. Sci.* **78**(4), 1185–1203.
URL: *http://dx.doi.org/10.1016/j.jcss.2011.10.008*

Shen, H. and Sun, C. (2002), 'Flexible notification for collaborative systems'.
URL: *http://doi.acm.org/10.1145/587078.587090*

Shen, H. and Sun, C. (2011), 'Achieving data consistency by contextualization in web-based collaborative applications', *ACM Trans. Internet Technol.* **10**(4), 13:1–13:37.
URL: *http://doi.acm.org/10.1145/1944339.1944340*

Shen, H., Sun, C., Zhou, S. and Phyo, Z. W. (2006), A generic webdav-based document repository manager for collaborative systems, *in* 'Proceedings of the 2006

IEEE/WIC/ACM International Conference on Web Intelligence', WI '06, IEEE Computer Society, Washington, DC, USA, pp. 129–136.
URL: *http://dx.doi.org/10.1109/WI.2006.14*

Simon, B., Anderson, R., Hoyer, C. and Su, J. (2004), 'Preliminary experiences with a tablet pc based system to support active learning in computer science courses', *SIGCSE Bull.* **36**(3), 213–217.
URL: *http://doi.acm.org/10.1145/1026487.1008053*

Simon, B., Davis, K., Griswold, W. G., Kelly, M. and Malani, R. (2008), Noteblogging: Taking note taking public, *in* 'Proceedings of the 39th SIGCSE Technical Symposium on Computer Science Education', SIGCSE '08, ACM, New York, NY, USA, pp. 417–421.
URL: *http://doi.acm.org/10.1145/1352135.1352278*

Simon, H. A. (1972), 'Theories of bounded rationality', *Decision and Organization* **1**(1), 161–176.

Socrative (2014), 'Socrative'.
URL: *http://www.socrative.com*

Stefik, M., Bobrow, D. F., Foster, G., Lanning, S. and Tatar, D. (1987), 'Wysiwis revised: early experiences with multiuser interfaces', *ACM Transactions on Information Systems* **5**(2), 147 – 167.

Steimle, J., Brdiczka, O. and Muhlhauser, M. (2009*a*), 'Collaborative paper-based annotation of lecture slides', *Educational Technology & Society* **12**(4).

Steimle, J., Brdiczka, O. and Muhlhauser, M. (2009*b*), 'Coscribe: Integrating paper and digital documents for collaborative knowledge work', *IEEE Transactions on Learning Technologies* **2**(3), 174–188.

Sun, C. and Ellis, C. (1998), Operational transformation in real-time group editors: issues, algorithms, and achievements, *in* 'ACM Conference on Computer Supported Cooperative Work', ACM, pp. 59–68.

Sun, C., Jia, X., Zhang, Y., Yang, Y. and Chen, D. (1998), 'Achieving convergence, causality preservation, and intention preservation in real-time cooperative editing systems', *ACM Transactions on Computer-Human Interaction* **5**(1), 63–108.

Sun, C., Xia, S., Sun, D., Chen, D., Shen, H. and Cai, W. (2006), 'Transparent adaptation of single-user applications for multi-user real-time collaboration', *ACM Trans. Comput.-Hum. Interact.* **13**(4), 531–582.
URL: *http://doi.acm.org/10.1145/1188816.1188821*

Sun, D., Xia, S., Sun, C. and Chen, D. (2004), Operational transformation for collaborative word processing., *in* 'Proceedings of ACM Conference on Computer Supported Cooperative Work', pp. 437 – 446.

Titsworth, B. S. and Kiewra, K. A. (2004), 'Spoken organizational lecture cues and student notetaking as facilitators of student learning', *Contemporary Educational Psychology* **29**(4), 447–461.

TouchType Limited (2008), 'Swiftkey'. Online; accessed 28-July-2015.
URL: *http://swiftkey.com/en/*

University of South Australia (2015), 'Graduate qualities'. Online; accessed 28-July-2015.
URL: *http://w3.unisa.edu.au/gradquals/*

Venkatesh, V., Morris, M. G., Davis, G. B. and Davis, F. D. (2003), 'User acceptance of information technology: toward a unified view', *MIS Quarterly* **27**(3), 425–478.

Ward, N. and Tatsukawa, H. (2003), 'A tool for taking class notes', *International Journal of Human-Computer Studies* **59**(6), 959–981. doi: DOI: 10.1016/j.ijhcs.2003.07.003.

Ward, N. and Tatsukawa, H. (n.d.), Software for taking notes in class, *in* 'Frontiers in Education, 2003. FIE 2003. 33rd Annual', Vol. 3, pp. S2E–2–8 vol.3.

Williams, R. and Eggert, A. (2002), 'Notetaking predictors of test performance', *Teaching of Psychology* **29**(3), 234–237.

Wirth, M. A. (2003), 'E-notes: using electronic lecture notes to support active learning in computer science', *ACM SIGCSE Bulletin* **35**(2), 57–60.
URL: *http://doi.acm.org/10.1145/782941.782981*

Xia, S., Sun, D., Sun, C. and Chen, D. (2006), An integrated session and repository management approach for real-time collaborative editing systems, *in* 'Proceedings of the Fourth International Conference on Creating, Connecting and Collaborating Through Computing', C5 '06, IEEE Computer Society, Washington, DC, USA, pp. 254–261.
URL: *http://dx.doi.org/10.1109/C5.2006.6*