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Higher Education Computer Science

A Manual of Practical Approaches

Second Edition

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ISBN 978-3-031-29385-6 ISBN 978-3-031-29386-3 (eBook)
https://doi.org/10.1007/978-3-031-29386-3

This Springer imprint is published by the registered company Springer Nature Switzerland AG
The registered company address is: Gewerbestrasse 11, 6330 Cham, Switzerland

Foreword: Higher Education Computer Science in a Post-pandemic World

The preface of the first edition of this book began with the phrase "it is cliché to say that higher education is changing". Little did the editors know then that a few years' later higher education, and life in general, would undergo an unprecedented change as a result of the COVID-19 pandemic. Swift action was demanded from academics across the UK and the world. The initial obligation was to move to fully online teaching and assessment almost overnight to be able to complete the academic year 2019/2020 in the midst of a national lockdown. The same academics then had to prepare for a year where flexibility and adaptability were an absolute priority, to cope with the inevitable disruption from staff and student illness, together with lockdown reactions to further outbreaks of the virus.

On this extraordinary journey, computer science academics had to overcome potentially one less barrier compared to academics in less computing-oriented disciplines: their digital literacy skills. Such academics engage with technology as part of their discipline, and as such, they were more able to embrace the challenges posed by an immediate transition away from face-to-face teaching. Prior to the pandemic, technology was in the main used to supplement the delivery of face-to-face teaching. As soon as the effects of the pandemic presented themselves, technology was *central* to the delivery of learning, teaching and assessment. This transition, however daunting, became a catalyst for innovative practice with many groundbreaking paradigm shifts, which the cases within this book serve to explicate.

However, some pertinent themes have emerged as a result of the rapid transference to online learning and our subsequent immersion in it ever since.

The demise of traditional lectures. The pandemic has led many lecturers to gradually move away from traditional oral, in-person delivery in front of a classroom. After experimenting with various alternatives during the pandemic years, from bite-sized recordings to flipped classroom settings, more sophisticated, learner-centred approaches to teaching have emerged. Whilst the traditional mode of delivery is still present when it is important to explain a complex notion or threshold concept, it is now often interspersed with student-led and tutor-facilitated activities that bear some resemblance to elements of synchronous online during lockdown periods. Several benefits to students result from this change, such as improved, deeper understanding due to active, practical learning rather than passively listening, and also increased confidence from working independently and as part of a team.

The importance of engagement. Many academics will have experienced the despair of sitting in a virtual meeting room asking a question to an audience whose cameras and microphones are switched off, and the joy of seeing a text message "pop-up" in the chat as a response after a few minutes, except that it felt like hours of silence. Situations like these led academics to explore different ways of making their sessions engaging and interactive, ensuring that students at home were actively participating and remaining interested and engaged throughout. Such good practice is applicable to any synchronous or asynchronous session, online or in-person and includes the use of interactive learning and presentation platforms such as Mentimeter and Kahoot to engage students. This is especially beneficial in the case of computer science students who often demonstrate more introversion perhaps than in other disciplines, and who might be less likely to respond directly to a question in front of others, but they are willing to engage through text-based chat or anonymised quiz responses.

Bite-sized learning. The aforementioned innovative delivery approaches have also had a significant influence in the way knowledge is packaged. Moving away from traditional in-person lecturing signifies a departure from large amounts of content delivered in one go, favouring instead bite-sized *chunks* of knowledge mixed with activities, quizzes, Q&A and other ways of assimilating knowledge. Bite-sized learning, in turn, requires a rethink of the way content is provided to students through virtual learning environments, encouraging more fine-grained clustering than large thematic blocks. This allows students to more clearly understand how different elements of taught material interact and the alternative learning journeys they can follow by navigating through content. From a tutor's perspective, there is the added value of being able to more accurately track the progress of students, as well as understand which content receives more attention (or engagement) than others, or which topics are more difficult to comprehend.

Re-thinking examinations. A major challenge for academics throughout the pandemic and afterwards has been to prevent academic misconduct in examination-based summative assessment that is conducted remotely. In many computer science courses, this has led to a gradual phasing-out of most end of year examinations, in favour of coursework-based summative assessment and formative online quizzes. Of course, examinations may still play an important role in modules of a more mathematical nature, but in modules whether there is a practice-based element, such as software development, assessing through a portfolio or project-based coursework may improve attainment by allowing students to apply and hone their skills over a longer period, rather than being assessed during a one-off 2-hour session for example. It may also reduce the likelihood of collusion by, for instance, including an individualised component within the coursework, so that if students collaborate, they can learn from each other, rather than merely copy from each other.

Management and leadership challenges. In a post-pandemic higher education, effective leadership is ever more important and far more challenging. In the aftermath of more than two years of increased workload as a result of preparing material or covering for missing staff, the risk of burnout has increased, especially if there is still disruption in one form or the other. Mitigating this risk requires managers to put mechanisms in place to maintain workload at reasonable levels, through robust staff contingency and continuity plans and moving towards leaner courses. In turn, workload rationalisation can improve the likelihood of maintaining the academic staff base even in times of high volatility by reducing staff turnover and increasing incentives.

On the whole, the pandemic period for computer science higher education has been as challenging as it has been transformative and despite the difficulties, especially at the beginning of the pandemic, rewards in the form of lessons learned and good practice have been significant. These add to a wealth of knowledge that preceded the pandemic and are still pertinent and influential. Computer science academics should strive to keep the best of both worlds, maintaining what is still suitable from before the pandemic and enriching their practice with successful initiatives that were borne out of the pandemic.

This second edition of the *Higher Education Computer Science* book is a manifestation of this, showcasing a wide range of practical approaches that have been developed by staff who did what they do best: making the teaching work.

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Preface

The preface to this second edition of this book discusses the radical changes that have been imposed on higher education as a result of the global COVID pandemic and the ensuing lockdowns. The sudden acceleration of the switch to a high proportion of online learning has changed the way in which higher education is delivered probably forever and has raised fundamental questions regarding the role of HE educators (a theme picked up in the postscript to the book). Many of these changes were in the wind anyway as the preface to the first edition noted, but the consequences of the pandemic have made it even more imperative that we question what we do and how we do it.

As the preface to the first edition noted, it is cliché to say that higher education is changing. There has been continuous change at least since the 1970s. Nevertheless, the changes that are occurring at the moment seem to be more profound and more widespread than ever. All institutions, however prestigious or uncelebrated are being affected. For some of the most prestigious, the shock of the change has been greatest, and this is new. Universities that have prided themselves on their research records are being asked to reconsider their teaching capabilities and their relationships with and attitudes to their students. They are being challenged on their records on student diversity. They are being required to justify their utility to the economy.

There are other forces at play. Increased competition for students between universities, (both globally and within country) and the requirement to be self-financing, are driving universities to satisfy prospective students that they offer value for money, both in terms of financial investment and the long-term skills students will need to prosper in a rapidly changing employment market. Technological change in the form of access to information, both about the universities themselves and the subjects they teach is powering a trend towards consumerism amongst students. People are asking the question "what are universities for?". Teaching materials in the form of MOOCs are freely available and of high quality; and if not, there, there is always Wikipedia. Social media has just about extinguished the last vestiges of deference. Finally, the global pandemic has driven even more resources online and probably changed the balance of online learning and face-to-face contact forever.

In the light of all these social changes, government continues to weigh in (and waded in) to insist on accountability. Initially (in the UK), this was to justify expenditure on research. More recently, the Office for Students and the "Teaching Excellence Framework" have sought to establish measures of student experience and teaching quality. The validity and even the reliability of these measures have been questioned, but whatever their academic credibility, the truism that "whatever we measure we change" has already affected the university sector.

Computer science and its related disciplines have been more exposed to these forces than most subject areas. The industry-oriented nature of the subject has resulted in high volatility in student application numbers as market trends affect demand for graduates. Technical change within the subject area has caused curricula instability. Waves from almost mystical adoration of computers and computing to commodified dismissal (what's the difference between a computer and a washing machine?) combined with perceptions of subject complexity and gender stereotyping, exacerbate the cyclical trends in subject's popularity.

These generic factors together with subject characteristics such as its basic intangibility and intellectual complexity have made CS and its allied subject areas inherently difficult to teach. Large student numbers lead to diverse student populations. Poor coverage of the subject area at pre-university level results in bipolar distributions of subject knowledge amongst university entrants. The gap between physical constructs and the subject's virtual concepts that create an intellectual schism students must navigate to make progress.

Teachers have been aware of these problems for many years and have tried various approaches to address the issues. Yet the increased pressure generated by the recent, intense scrutiny has meant that the urgency to find solutions has intensified further. This book gathers together a range of approaches that individual instructors have found helpful in addressing these common problems. These are practical applications that experienced practitioners have adopted to meet the needs of their students. The combined experience of contributors to this book is approaching 500 years. We cannot claim to have found solutions, that are unlikely to ever happen. But, by bringing together this community of practice in one volume, we hope to stimulate your own ideas, vitalise your teaching and enhance your practice.

The book is divided into three parts: *'Approaches to Learning'*, *'Teaching: Examples of Practice'* and *'Employability and Group Work'*. The *Approaches to Learning* part, whilst based on personal experience as is the whole book, offers some ideas about how we can move away from didactic delivery stage front. The *Teaching: Examples of Practice* part addresses some specific problem areas in teaching CS: programming, information systems management and design as well as some ideas about delivery to diverse student cohorts and automatic marking of programming work. The final part, the *Employability and Group Work*, does what it says on the tin, providing some novel ways of approaching employability.

Liz Coulter Smith's opening chapter on student "multitasking" in the classroom, in some ways, does not quite fit with the rest of the book as it is not strictly focussed on computer science students. It is included here because (a) computing students are amongst the most likely groups of students to engage in multitasking and (b) by looking at the changed culture and experience this current generation of students have grown up with, it sets the scene so well for the chapters that follow. Diane Kitchin's chapter on active learning offers one of the ways in which we can respond to these changes and address our students' needs and expectations. The "flipped" classroom, Michael O'Grady's chapter, provides an alternative approach. Clive Rosen's chapter offers a theoretical perspective on learning to program that presents an alternative approach to the program wars debate. Jenny Carter and Francisco Chiclana's chapter on distance learning and Thomas Lancaster's chapter on academic integrity address two issues that have arisen as a consequence of technological change affecting the classroom environment. Finally in this part, Marcello Trovati's chapter on teaching data science in context addresses the issue of the interconnectivity of computing with many other subject areas and advocates a multidisciplinary approach.

All the chapters in this part share a common orientation; they are student-centric rather than lecturer-centric. This attitudinal shift is one that might not sit comfortably on the shoulders of some staff, but we consider it to be essential if we are to engage with and maintain the engagement of our millennial students. Furthermore, if we can enhance the quality and quantity of engagement, we have a better chance of satisfying the expectations of other stakeholders as well as the students.

Part II, focussed on teaching, arises out of the knowledge and experience of the contributors to this book, of the teaching of computing. It addresses how we can best overcome some of the specific difficulties computer science students face in this most abstract, yet practical of subjects. Dave Collin's chapter offers an approach using graphics to overcome these difficulties with a smile. Steve Wade's chapter is similar, but focusses on information systems management and Carlo Fabricatore and Maria Ximena Lopez look at systems design. Arjab Singh Khuman's chapter takes a broader perspective on student engagement by looking at style rather than content (though he covers both). The section is rounded off by Luke Attwood and Jenny Carter offering some relief for hard-pressed markers of programming assignments. As student numbers increase, resources reduce and pressures on academics grow, this is something more of us may need to become more interested in future.

Part III of the book on employability and group work offers some guidance on how to embrace the employability agenda without compromising academic standards. The Enterprise Showcase outlined by Gary Allen and Mike Mavromihales offers one solution, whilst Clive Rosen's chapter on group projects provides a framework for decision-making regarding the running of group projects as well as some practical suggestions. Chris Proctor and Vicky Harvey suggest that satisfying employers' expectations compliments rather than compromises the learning process. Michael O'Grady and friends cover the question of managing year-long student placements, preparing students for it, supporting them during it and helping them readjust on their return. Sue Beckingham's two chapters complete this part by examining the skills and awareness today's students need. The first addresses the soft skills required by employers and the second, how to make students aware of their online presence and the importance of managing it for their future prospects.

The philosophy underpinning this book is that the relationship between student and instructor is fundamental to the success of the student. It needs to be built on mutual respect and regard. We aim to maximise the achieved potential of students. The approach is facilitative rather than didactic, supportive rather than patriarchal. This may not suit all pedagogic styles or all students, but we believe that a transition from the traditional master/pupil approach is essential to meet the current and future demands of the educational environment.

One word of caution: students have not necessarily, and may not, buy into the contract of having to commit their own time and intellectual effort in order to be successful. This can be a source of conflict between student and staff. However, one of the implicit terms of the contract is that staff must commit to seeking the best approaches to support the learning of their students. This cannot be abrogated even if students don't keep their part of the bargain. We hope that this book will be of aid to teachers seeking to meet their obligations. There are many of us out there!

Two final points:

1. We are aware of the semantic controversy between the use of the terms pedagogy and andragogy, but we do not wish to intervene. In this volume, both terms are used interchangeably.
2. Similarly, the terms "teaching", "lecturing", and nouns "instructor" and "facilitator" are all used in the spirit described above, to support student learning.

We hope you find this book helpful, informative and, dare we say it, enjoyable.

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Part I
Approaches to Learning

Chapter 1
Changing Minds: Multitasking During Lectures

Liz Coulter-Smith

Abstract This chapter takes a multidisciplinary approach to multitasking. Media multitasking has, consequently, become a frequent topic amongst academics yet some remarkable new research is revealing that we may not be taking into full account the changes to our students' ability to learn, given the changes to their brains. The risks of multitasking to student achievement have been well researched yet many of the positive related developments in neuroscience are less well known. This chapter reviews some of this research bringing together: information foraging theory; cognitive control; and confirmation bias as they relate to the multitasking Generation Z student in higher education. Some significant research findings are discussed, including using laptops and similar devices in the classroom. A small survey underpins these discussions at the end of the chapter, highlighting student perspectives on multitasking during lectures.

Keywords Multitasking · Cognition · Information foraging · Academic performance

1.1 Introduction

It is in our nature to do more than one thing at a time: to multitask. Multitasking feels good. Dopamine is released every time we turn to a new task (Strayer and Watson 2012). Our motivation to multitask is a natural human urge—we are foragers, and more recently in our technological history, information foragers (Pirolli and Card 1995).

Multitasking is defined as using two or more media concurrently. It is slightly different from task switching where one switches attention between two tasks. They are closely related, but for our purposes, we will define multitasking, sometimes referred to as media-multitasking, as involving at least one device that coincides with the "performance of two or more functionally independent tasks with each

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J. Carter et al. (eds.), *Higher Education Computer Science*,
https://doi.org/10.1007/978-3-031-29386-3_1

of the tasks having unique goals involving distinct stimuli (or stimulus attributes), mental transformation, and response outputs", (Sanbonmatsu et al. 2013).

Multitasking with various devices is also commonplace in university classrooms (Junco 2012). Three out of four students believe technology improves their educational experience and since 2015, 90% of students have both laptops and smartphones[1] (Statista 2017). Media device dependency, especially among 18 to 20-year-olds, shows 44% are compelled to access a device at least once every ten minutes (VitalSource/Wakefield 2015). These factors are profoundly impacting student focus, attention, distraction and consequently academic performance. Nonetheless, these factors are complex yet offer possible solutions that may require substantial shifts in thinking, both on the part of the student and the lecturer.

This chapter discusses why students are compelled to multitask particularly around information-intensive activities. The focus is on multitasking in the classroom of first-year university students but also attempts to understand the current multitasking debates including some problems involved in attention and distraction in the context of teaching computer science in higher education. This discussion then delves into a few of the recent studies in neuroscience to better understand the complex relationships that underpin multitasking. To summarise, this chapter seeks to expand the discussion on multitasking through the lens of a multidisciplinary approach to the topic. Through a small pilot survey at the end of the chapter, we gather data drawn from a group of first- year computer science students as first-hand evidence of the state of the debate.

1.2 Information Foraging Theory and Multitasking Check Para Numbering Here

We have to ask why humans have a compulsion to multitask? What is driving this urge? One theory stands out and helps make sense of this innate drive to multitask where we are in pursuit of information-intensive tasks. Understanding this problem from a behavioural position is vital given the context of teaching and learning in the classroom and given the increasingly sophisticated social and technological tools at the students' disposal. Information foraging theory (IFT) was developed at the Palo Alto Research Center (PARC), to develop project models for the User Interface Research Area, this theory provided 'novel' information visualisation for searching and browsing (Pirolli and Card 1995, p.50). IFT goes some way to explaining our drive as humans to accumulate information. This theory is particularly important due to the level of information available to students and their drive to multitask and task switch. The IFT research team primarily used participants from the areas of business intelligence and MBA students. The team quickly realised the depth and variety of phenomena that needed to be dealt with when handling massive volumes of information, deadline constraints and complex search decisions in the context of uncertainty.

[1] Between 2011 and 2017 smartphone use doubled from 21.6 to 44.9 million in the United Kingdom.

Early on they realised they were dealing with something different from the standard human–computer interaction tasks originating from cognitive engineering models of the 1990s. Comparatively, they recognised the behaviours of people seeking information was largely determined or shaped by the architecture of that content, also referred to as the *information environment.* It was clear the participants' behaviour was only minimally shaped by the users' knowledge of the user interface. What is interesting here is how this model maps onto the classroom and the context of learning since Pirolli also found behaviour tended to be dominated by uncertainty and continual evaluation–a common attribute when learning a new skill or concept. Information foraging theory (IFT) was theoretically developed from optimal foraging theory (OFT) (Krebs 1977). OFT is largely a theory developed from predictive models of decision rules used by predators and originating from the theory of natural selection focussed on maximising food intake during foraging (MacArthur and Pianka 1966). Generally, IFT theory asserts that we have evolved to use information to solve problems that can pose a threat to us and our environment. Rather than forage for the food, we now forage for information. The theory goes on to explain that we have adapted cognitive solutions for survival. The technological need for survival forms a basis for human interaction with information technologies as demonstrated by the World Wide Web (Pirolli and Card 1995, p. 51). The earliest discussions about multitasking borrowed heavily from the biological sciences in this paper. The book that followed twelve years later, 'Information Foraging Theory' (Pirolli 2007) is a singularly foundational and influential work. More recently and no less important is 'The Distracted Mind' (Gazzaley and Rosen 2016) which further develops information foraging theory from a neuroscience perspective. These two works, bringing together information and neuroscience, place a plausible bridge for researchers attempting to explain the phenomenon of the human drive to multitask. If we consider this as a partial framework or model for further exploration, then there is a more positive perspective on multitasking than has previously been published since one can then view it as part of our natural evolution and adaptive ability to gather and make sense of increasingly large volumes of information and data in this era.

1.3 Multitasking Is Multidisciplinary

It became apparent that there was a need to expand this chapter beyond the issues of education and to consider the advances in neurosciences and cognitive psychology. It was apparent that media multitasking and its effects have been investigated exhaustively in many ways. "The problem of how the brain undertakes multiple tasks concurrently is one of the oldest in psychology and neuroscience" (Verghese et al. 2016).

In 2009 a summit at Stanford University's Center for Advanced Study in Behavioural Sciences (CASBS) considered the impact of multitasking on learning and development. The purpose was to pull together a multidisciplinary, coherent and scholarly research agenda. Participants came from the field of neuroscience, child development, cognitive science, communication, education, and business policy. Terms were agreed, including using the word multitasking itself, that multitasking had become a universal problem needing urgent attention. Solutions were being demanded by parents, educators, employers, workers, and marketers. Clifford Nass, a professor of communication at Stanford noted, "If you mention multitasking, people go insane—it's all they want to talk about". He described the problem of multitasking as "a challenge to human cognition" (Ophir et al. 2009).

1.3.1 Multitasking and the Brain

To better understand how distraction relates to multitasking we will explore a few aspects of neuroscience and our mechanical sensory capacities. To interpret multitasking, we need to consider the brain's attention networks underlying our ability to switch tasks (Rothbart and Posner 2015, p. 3). Neuroimaging has recently revealed that even subtle shifts in tasks activate neural areas (Rothbart and Posner 2015). The cerebellum has two areas of operation one that uses sensory signals and the other uses motor signals. In effect, the cerebellum is our *motor* for learning, particularly when it comes to learning new motor skills (Hatten and Lisberger 2013, p. 2). The cerebellum is capable of plasticity allowing a neuron to communicate with another neuron (this is a simplified explanation) in dynamic ways. For the most part, the mechanical and sensory parts of the brain operate together as long as a single task is involved. However, introduce more than one task and communication between these parts begins to break down resulting in the grave consequences of driving and texting (Kramer et al. 2007). Most of us have experienced 'going on autopilot' and driving from one destination to another without being fully conscious of the trip. This is experienced since we were likely thinking about something else during the mechanical process of driving–the learned mechanical process of driving has been saved to memory. However, introduce another mechanical process, say picking up a mobile, or a third–using ones' fingers to text, and even a fourth composing a text, and you have a recipe for disaster–the entire process becomes significantly diminished. In the United States alone nearly half a million people were injured or killed in accidents involving this combination of texting and driving (U.S. Department of Transportation 2017).

1.3.2 Action-Based Learning

The environment is significantly different in the classroom, still both the sensory and mechanical parallels for the brain exists with much less catastrophic consequences. Impaired listening or attention are significant to those trying to convey information to students who may be generally unaware that they are missing much of what is being said. Recent research on plasticity regarding learning suggests that physical movement may activate the hippocampus in ways not previously understood (Cassilhas et al. 2016, p. 168). This discovery is significant concerning Action-based learning (ABL) approaches, since movement supports how the brain connects to preparing itself to learn. ABL is a process or pedagogy of brain-activated learning linked to the action of motor skills. This approach fits in well with the learner, requiring greater stimulus yet it has been observed that ABL is rarely discussed as a potential solution or even partial solution to the problem of distraction or inclination to excessively multitask in the classroom. (An omission that is addressed in this volume in Diane Kitchin's chapter on active learning.)

The problem of how we help students manage or break the cycle of multitasking in class may be diverted or rewired using methods like ABL. ABL requires substantial changes to the way lectures are planned and executed. The current state of most lecturing methods, where a long talk is involved, is yet another reason why lectures are becoming less able to facilitate learning and why ABL has come to the fore as one potentially rich approach.

1.3.3 Gen Z and Boredom

This year (2018) we will see our first Generation of students born between 2000 and the present: Generation Z (Gen Zers or Gen Z) has arrived in higher education. This generation was born into an Internet-connected world, has grown up with the smartphone, and may have spent the past decade using many social networks. The Gen Zers are a generation that prefers communicating through social media over direct communication. For the Gen Zers, waiting is not much of an option and they are conditioned to pick up their smartphone or device and find a release from the boredom. Since the arrival of the smartphone, waiting in lines at the store or for a train have become less of a problem. We can fill that time perusing the news, checking our social networks and email. Gen X and Zers use technology to 'personalise everything', they are technologically skilful and prefer Web applications and email (Reisenwitz and Iyer 2009, p. 91).

It seems logical that if students are physically active and working towards a goal or a solution to a problem they will be less likely to stop, pick up their phone and check Facebook–they will be less likely to want to interrupt their processes due to boredom.[2] This generation gets bored fast and the antidote to a nice hit of dopamine in checking in to social media. It activates them, and physiologically this generation has become accustomed to multitasking in this way in the same way that we would probably receive a similar hit from eating something satisfying.

[2] Our survey found 55% of students multitasked due to boredom. 62% identified lecturers reading from slides as another cause for multitasking during formal lectures.

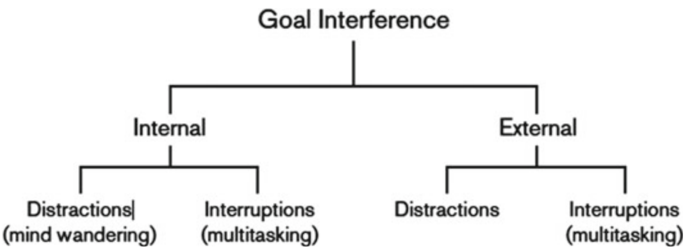

Fig. 1.1 Gazzaley's conceptual framework for goal interference

1.3.4 Cognitive Systems and Control

Cognitive control and its functions are central to the concept of multitasking. Although we cannot pursue this in depth in this chapter, some basic concepts are considered. Gazzaley breaks this down into internal and external factors about interference (see Fig. 1.1 (Gazzaley and Rosen 2016)). Interference represents those things that distract and interrupt us whether of our internal making or externally driven. The brain is a complex information-processing system. As a system, it is structured and optimised for performance. Again, in Fig. 1.1, Gazzaley shows how goal interference competes with internal and external factors as we try to achieve our aims.

Students, however distracted, are just trying their best to achieve their aims with often incomplete information about how to manage themselves. Perhaps there is a need to help them understand how they can optimise their work through understanding some concepts around multitasking. As discussed earlier, they are living in a more distracted environment than existed a decade ago or for us as academics when we were taking a degree. Of course, experience and management of goal interference will likely swing widely between the individual depending on countless variations. However, several areas can be supported in the classroom by adjusting our teaching methods, by considering recent research, and by embracing rather than negating technological changes.

1.3.5 Confirmation Bias and Supertaskers

Another issue brought up in both our survey and anecdotal with first-year students is the role confirmation bias plays alongside multitasking. Over the past two years, there has been a higher proportion of students who believe they are 'supertasker's' capable of rapid attention shifting with devices in what they believe to be efficiency. It is often talked about as a sought-after skill. It is true the way students often interact with a keyboard and respond to screen-based information is fast. Many studies have tested the supertasker phenomenon (Watson and Strayer 2010; Carr 2010). However, current laboratory research still asserts that simultaneous task performance suffers during multitasking (Dux et al. 2009; Garner and Dux 2015). The problem is that speed and fluidity do not necessarily translate into the ability to apply it and learn new skills. Even more problematic, how do we help students to understand this when they believe what they have in a sense become indoctrinated into a cult of speed and freedom of unfettered access. Furthermore, studies of the brain have shown (Watson and Strayer 2010; Strayer and Watson 2012) there are only 2% of individuals capable of multitasking or do more than one thing at a time efficiently. However, employers seem to believe multitasking is a sought-after skill and regularly advertise it as such in programming jobs.[3] Also, students see other students with similar behaviours in class and come to believe that doing more than one thing at once is expected of them, to further exacerbate this problematic issue.

1.3.6 Academic Writing: A Bridge Too Far

Writing is a higher-order learning skill. It is also an area where academics have seen significant and growing difficulties for students. It is possible that the rise of essay mills may well be related to the problems students are facing having to write an extended academic paper. If, as mentioned earlier, many students are experiencing a reduced depth of processing, increasing stress levels including anxiety due to multitasking, then their ability to invoke creative problem solving will ultimately be hampered (Firat 2013). We are finding that fewer students are often only capable of shallow focus work (Carr 2010) leaving them unable to tackle harder work requiring greater cognitive power and focus. So it is not only the focus, but academic writing is a difficult task that requires deeper thinking and higher cognitive skills than what current students spend most of the time doing, both inside and outside the higher education environment. These problems become most visible in the third year when they are asked to develop a dissertation, a large piece of writing requiring work over an extended period. They are less prepared for this challenge, and we need to do more to assist them constructively. It is likely that various variables are at work here from brain and neurological functioning to insufficient awareness and ability to manage distractions effectively. Add to this the inability to manage and focus attention in the sea of the increased use of social media, all these factors are contributing to the problem.

GOT TO HERE.

[3] Searching the word "multitasking" site:indeed.com and "multitasking" site:indeed.co.uk show a difference of 73,300 US compared to 6760 UK. This may suggest a difference in educational and employment emphasis. It could also be just a reflection of population differences.

1.4 Debating the Banning of Laptops During Lectures

Moving now from our increased understanding of why students multitask and how the brain functions we can further explore the impact these are having in the classroom. One of the standout factors aligned to multitasking in the classroom is social media usage. In 2005 Facebook and MySpace were launched, closely followed by Twitter and YouTube in 2006. The exponential shift happened a few years after the launch of smartphones including the iPhone in (2007), and the 2008 launch of the Android mobile operating system in 2008. It then took several years for mobile computing to appear in classrooms where more than half the class were in possession of a mobile. In 2010 only a few students had them, but the increase has become pronounced and new problems around attention and distraction arose. Smartphones are cheaper, faster and the operating systems less fraught with technical issues. By 2015 virtually every student had a smartphone in the classroom and often more than one device. This fast pace has put stresses on the higher education system and our ability to adapt our teaching methods at pace with these changes. Combine this with social media usage, and one has a perfect storm.

By the fall of 2016, social media usage amongst university freshman in the United States averaged over six hours a week, an increase of over 40.9% or 27.2% greater than in 2011 and 2014 (HERI 2017, p. 20). There were over 10 million participants in this survey. Being an election year in the United States may have had some impact on this data. However, if social media continues to increase at a similar rate, what changes are likely in the classroom? Will increased usage of social network sites (SNSs) amongst students increase distraction and attention levels in the classroom and if so how will we adapt our methods? It is essential to develop strategies to improve engagement in this changing environment as well as considering both cognitive and information systems models as part of that development. As professors and lecturers across the globe experiment with various approaches to control these relatively recent changes, we see both extreme and light touch reactions. One wing demonstrates only a modest understanding of the collision of human-to-human and human–computer interactions at play. For example, Seth Godin[4] taking an oppositional stance towards Susan Dynarski, a professor at the University of Michigan. Dynarski published an op-ed in the New York Times stating that she has forbidden students from using laptops in her lectures (Dynarski 2017). Godin believes Dynarski has missed the point altogether. According to Godin, Dynarski is laying the blame in the wrong place by asking students to slow down their clock speed and listen attentively in addition to notetaking—all at the same rate. He argues this is unreasonable to expect this given the technological changes in recent years and lays some blame on universities not adapting quickly enough either. Godin states "the solution isn't to ban the laptop from the lecture it's time to ban the lecture from the classroom" (Godin 2017). He also believes the lecture should be digitally recorded so students can review it, as and when they choose to. However, the problem may not require institutions to do away with

[4] Seth Godin is a well known entrepreneur, bestselling author, writer and marketing and leadership blogger.

the lecture hall, and it is worth considering the possibility of something in between these two somewhat extreme ends of the spectrum. Shorter lectures formed of no more than five to seven minutes followed by activities to discover information closely related to the presentation may be more motivational and engaging. The traditional 45–60-min lecture is still currently the norm but is unsustainable given the changing environment. There are a number of arguments against banning laptops, not least of whether such a ban would be compatible with an ethos of open education and how such a ban might be enforced. There is the question of potential discrimination against students with disabilities, or if some students were allowed laptops to support their disability, discrimination against students without disabilities. Furthermore for "Zers" a laptop or smartphone may be the most efficient way to take notes and to instantly look up additional information. Some research suggests that students who multitask using their laptop during lectures perform less well compared to those that do not (Sana et al. 2013). However, one must ask—if students had more advice on *how* to take notes optimally, would this study still be valid? The early days of email usage in the mid-nineties had a pretty steep learning curve and compared to numbers of technologies and applications we have now it seems an almost silly comparison, yet we all struggled with learning how to manage it. Academic staff misused and overused the medium while simultaneously bemoaning the extra workload. We may have to consider students similarly don't know *how* to manage their devices optimally to improve their performance. Sana's study above was only investigated with forty participants. A limited sample suggests a need for a more comprehensive study that also considers using an intervention method as a control group and then comparing the data similarly to a study undertaken at Ryerson University (Tassone et al. 2017, p. 1).

1.4.1 Note-Taking

The research on note-taking goes back to the 1960s where there was considerable debate about how and when to listen and take notes (Eisner and Rohde 1959). It is worth having a brief look at how note-taking fits into the multitasking debate. Many researchers believe that taking notes on a laptop will impair performance compared to those who take notes longhand (Mueller and Oppenheimer 2014, p. 1; Bellur et al. 2015, p. 65; Fried 2008, p. 47). The problem is not the technology or mandating rules to comply with it. The problem is more precisely that students need assistance managing the interplay of these issues. Generally, most studies tend to support a rule or discipline-based solution in the classroom more or less finding fault with the student, the technology or the social media networks and default towards asserting that students must follow "proper rules […] and abide by these rules" (Anshari et al. 2017). This approach mainly describes the problem but misses the importance of considering a model sensitive to context, changing cognitive conditions and human-systems design persistently shaping behaviour and influencing human evolution.

1.5 Smartphone Dependencies

Dependency on smartphones and academic performance is another area aligned with variables contributing to multitasking. There has been a plethora of research over the past decade on this topic (Samaha and Hawi 2016; Junco 2012, pp. 505–514) is well- documented students were almost in a state of discomfort having to turn off or look away from monitors or devices during the formal part of a lecture. There are many issues at work here. Firstly, students have become used to large amounts of visual activity and stimulus with the average 19-year-old checking their phone every ten minutes. Secondly, most students have had a smartphone for at least five years or more and lived in a context where these technologies have been an inseparable part of their daily lives. The smartphone has become an object of instant gratification, a quick fix for boredom and has neurologically altered their brains and consequent behaviours. Often this is leading to a form of addiction (Terry et al. 2016, p. 245). We can now confirm this has changed our students' brains having grown-up in tandem with smartphones and mobile computing more (Loh and Kanai 2015, pp. 2–3). If we can accept this, then much of what has been discussed in this chapter should begin to make sense. With this in mind try to imagine what a student would be experiencing in the average university classroom. Imagine how frustrating it would be to sit for extended periods while the lecturer reads from slides. This approach is still occurs in many lecture halls in both the United States and the UK. The lecture format will likely not keep students engaged unless it is short (5–7 min), targeted and has a specific outcome followed up quickly by an information consolidation activity. So, we currently have a problem, and it is not with the student–we are missing opportunities to create engagement in the classroom.

1.6 The Survey

A survey on multitasking was carried out between March 21st–31st 2017 on a cohort of 60 undergraduate students taking a first-year, core, web development module. The students were asked to describe their multitasking habits during formal lectures. The study aimed to discover perceptions about multitasking behaviour.

A Likert scale was used for 22 questions. A 23rd question asked if they would like to share their thoughts. The Likert scale was especially useful for establishing some evidence of a possible correlation between high percentages of neutral answers and whether questions were either too broad or vaguely stated. (Thedetail of these results has not been included.) The highest neutral score was 42% for the question: *I believe multitasking during lectures is a smart thing to do.*

1.6.1 Intrinsic Questions

Four questions were similar for a reason. These were questions about whether participants would change their minds about multitasking. 60% were willing to change their minds if multitasking proved to them it could: lower or improve their grades (66%), harm their learning (60%) or improve their learning (48%). 55% believed they could get more done with 43% thinking it made them more efficient.

1.6.2 Extrinsic Questions

Just 58% of the students said they were using one or more devices to multitask during their formal lectures. This result is generally in line with other studies. The reason for this appeared to be that they felt they could get more done 55%, while 62% said they multitasked because lecturers were reading from slides, while 55% said their multitasking was due to boredom during the lecture. In some ways, this is encouraging as a change in teaching approach may result in more active or participatory learning. No students felt any pressure to multitask by their lecturers (0%).

1.6.3 Employability

In 2012 at the CASBS summit, Clifford Nass stated: "companies now create policies that force their employees to multitask". In our study, just 11.7% thought multitasking would make them more employable. This result demonstrates an opportunity to raise awareness amongst students for employability purposes. Oddly, 40% said they believed multitasking to be an essential skill. There has been an increasing frequency 'multitasking' appearing in job posts for software developers. This response is interesting despite evidence multitasking skills are often sought by employers. However, there is a difference in emphasis between the United States, and the United Kingdom[5] in this regard. Oddly respondents did not consider multitasking to be an employability factor as highlighted in some research (Burak 2012; Crenshaw 2008).

The survey shows some evidence that computer science students in the UK have varied views on whether multitasking during class lectures is positive or negative. Though one comment did not see the point of the survey or why their views about it would be interesting. This response suggests students need more information about

[5] Searching the word "multitasking" site: indeed.com and "multitasking" site:indeed.co.uk show a difference of 73,300 US compared to 6760 UK. This may suggest a difference in educational and employment emphasis. It could also be just a reflection of population differences.

this for their continuous and focused information-seeking behaviours about multitasking. Similarly, lecturers may want to alter teaching methods to reflect the changed cohort as mentioned earlier. Students also appear to want the facts about multitasking as there seemed to be some slippage between what they believe and what may help them in their studies and professional life.

1.7 Conclusion

Early on in this research project, it became apparent that the study needed to expand beyond issues of education and therefore consider the recent advances in the cognitive neurosciences and cognitive psychology. It also became clear that media multitasking and its effects have been investigated exhaustively in many ways. "The problem of how the brain undertakes multiple tasks concurrently is one of the oldest in psychology and neuroscience" (Verghese et al. 2016). What has been offered in this chapter is the breadth and depth of the challenge ahead and to some extent behind us as mediators in the classroom. Further advancements and changing frontiers in the sciences are still being discovered and how much Gen Zers brains have been altered is becoming apparent. However, as Susan Greenfield asserts "the brain is exquisitely adaptable" (Greenfield 2015) and further research will likely bring enhancements possible for our ongoing adaptation concerning information foraging. It is also possible that with these advancements there will be more 'supertaskers' among us (Strayer and Watson 2012). Video games are an indication of this and have been shown to be highly beneficial to multitasking particularly with older participants (Mishra et al. 2016). These developments indicate not all aspects of multitasking mean poor performance as some researchers assert (Bellur et al. 2015, p.65). Changes are underway that will continue to test us as educators though, and students will require specific and targeted guidance about the risks and benefits of multitasking has as they manage their courses, careers and lives. However, I would suggest that there is one conclusion we can certainly draw. Multitasking is prevalent, and it is here to stay. We can either choose to rile against it, or adapt our methods to accommodate it. Accommodation would seem to be the more productive approach and possibly the less stressful one. It might well be worth considering how best to incorporate the changes learning environment into our teaching.

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Chapter 2
Active Learning in Large Lectures

Diane Kitchin

Abstract An increasingly diverse student body combined with pressures to demonstrate excellence in teaching and improve results presents challenges for lecturers. Active learning techniques have attracted interest and discussion amongst educationalists. This chapter investigates the challenges and gives a practical guide to techniques that have been used effectively in a large lecture situation with first year students.

Keywords Active learning · Large lectures · Computing education · Constructivism

2.1 Introduction

Changes in higher education over recent years have seen a rise in the number of students going to University and consequently a more diverse student body. This has led to a need to help students make a smooth transition between school and University and to adjust to different environments, different delivery styles and different expectations. With increased competition for students amongst Universities, and the new demands of the Teaching Excellence Framework (TEF), comes increased expectations on lecturers—we must ensure our students pass our modules, and moreover pass them with good marks. Excellent and effective teaching is seen as a key factor by Universities in attracting students to their courses. The University of Huddersfield mentions the quality of its teaching in four out of six of the factors that demonstrate its excellence on its 'About us' page for new and prospective students. (University of Huddersfield 2018). Active learning pedagogies was one of the themes identified by the Higher Education Academy (HEA) in its review of the written submissions Universities included as part of their TEF documentation, in support of the assessment criteria for Teaching quality, Learning environment and Student and outcomes learning gain. (HEA 2017). In the HEA report on TEF 2 the authors state that "Course

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J. Carter et al. (eds.), *Higher Education Computer Science*,
https://doi.org/10.1007/978-3-031-29386-3_2

design comes out as a prevalent aspect for providers upgraded to a Gold award …. Features mentioned in some statements included: … use of active learning…" (Moore et al. 2017)

Additional challenges to providing an active learning experience are that group sizes are often large, particularly for first year teaching, where lectures may be delivered to groups of 150 students or more. At Huddersfield with this diversity in the student body we have seen an increase in the number and level of student support initiatives. We have also seen a shift in the type of learning activities available, with more studio work, project work and group work. Research in approaches to learning advocates a more learner-focused approach in teaching, with active learning being much-discussed over recent years.

In this chapter we focus on the practical techniques adopted to overcome these challenges and foster an active learning environment, particularly in a large lecture situation. The remainder of this chapter is structured as follows: Sect. 2.2 discusses the challenges and motivation for this work in more detail; Sect. 2.3 describes active learning and reviews some of the literature; Sect. 2.4 describes the specific, practical techniques used to deliver active learning in a large Computing Science & Mathematics lecture; Sect. 2.5 reflects on outcomes and the use of these techniques and looks at possible further development and Sect. 2.6 gives a summary and presents our conclusions.

2.2 Challenges and Motivation

The specific context for this discussion is the delivery of a Computing Science & Mathematics module to first year students. This is a long-running module, which has existed in some form or another for many years, and which has been delivered by me for almost 10 years. It covers topics such as set theory, graphs and trees, propositional logic, sorting algorithms, Finite state automata, grammars and languages, regular expressions, binary search trees and tree traversal algorithms. It is typically taken by a very large group of around 100–170 students. Invariably, there will be a very wide range of abilities in each group. Some students won't have done any Maths since GCSE two or more years previously and may only have a grade C. Others will be very able students who have studied A-level Maths or Computing or both, and so they may have covered some of the topics already. There will also be a small number of mature students, who could have been out of formal education for a number of years, and who may be nervous about the subject. There will also be a number of international students, who may have had very different educational experiences. Again some of them will have covered similar material before, while others may not. A large mixed-background, mixed-ability group presents many challenges. How can we keep the attention of and give new challenges to students who are familiar with a topic, whilst not overwhelming and alienating students who view the material as difficult and possibly scary?