Jisc

Guide to the intelligent campus

Using data to make smarter use of your university or college estate

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The intelligent campus

Using data to make smarter use of your university or college estate

Contents

Introduction

It was raining, and Leda was off to her University for the day. Her phone had already sent her notification to leave for campus early as there was a lot of traffic on the roads and the buses were being delayed. She got to the bus stop earlier than usual and within a few minutes the bus arrived. On the bus, on her phone using the University App, she looked over her schedule for the day. There were lectures, a seminar and she also had a window to get to the library to find those additional books for the essay she needed to hand in next month. She was hoping to catch up with some friends over coffee. There were some notifications in the app, the seminar room had been changed, there was a high chance that the library would be busy today. Leda looked out of the window of the bus at the rain. Today was going to be a good day.

We're working on ways to improve the student experience by capturing and analysing the many kinds of data that can be collected across university and college campuses.

This research is developing alongside our effective learning analytics project and our work to build a learning analytics service.

At the core of the learning analytics service is the learning data hub where academic and engagement data is collected, stored and processed. We'll extend the learning data hub to enable data to be gathered in from physical places (movement trackers, heat and CO_2 sensors, for example) and from systems that record and monitor space and equipment usage, timetabling and other activities.

By analysing when and how rooms are used organisations will be able to make smarter, more effective use of learning spaces and other facilities across campus and to improve curriculum design and delivery.

Making timely interventions to ensure that the best available spaces are being used for each session will enable students to learn more effectively and ensure that the organisation is running efficiently – but this is only the start. Longer-term the possibilities for the intelligent campus project are practically limitless.

Project information

Our project aims to find effective ways to use data gathered from the physical estate and combine it with learning and student data from library systems, the virtual learning environment (VLE) and even on-site cafes and bars to:

- Give students a richer experience of learning and teaching so they can achieve higher grades
- Enable students to optimise the comfort and convenience of their physical environment

Further down the line, data from an intelligent campus could help students to:

- Navigate their way around the site
- Find appropriate pastoral or other support
- Share information about events
- Meet up to socialise or work collaboratively

Supporting students in these practical ways will help them settle in more quickly and learn better.

An intelligent campus could also enable organisations to reduce their environmental impact by monitoring and managing energy use in real time, to streamline waste management, to move supplies around site more efficiently… the list of potential benefits goes on.
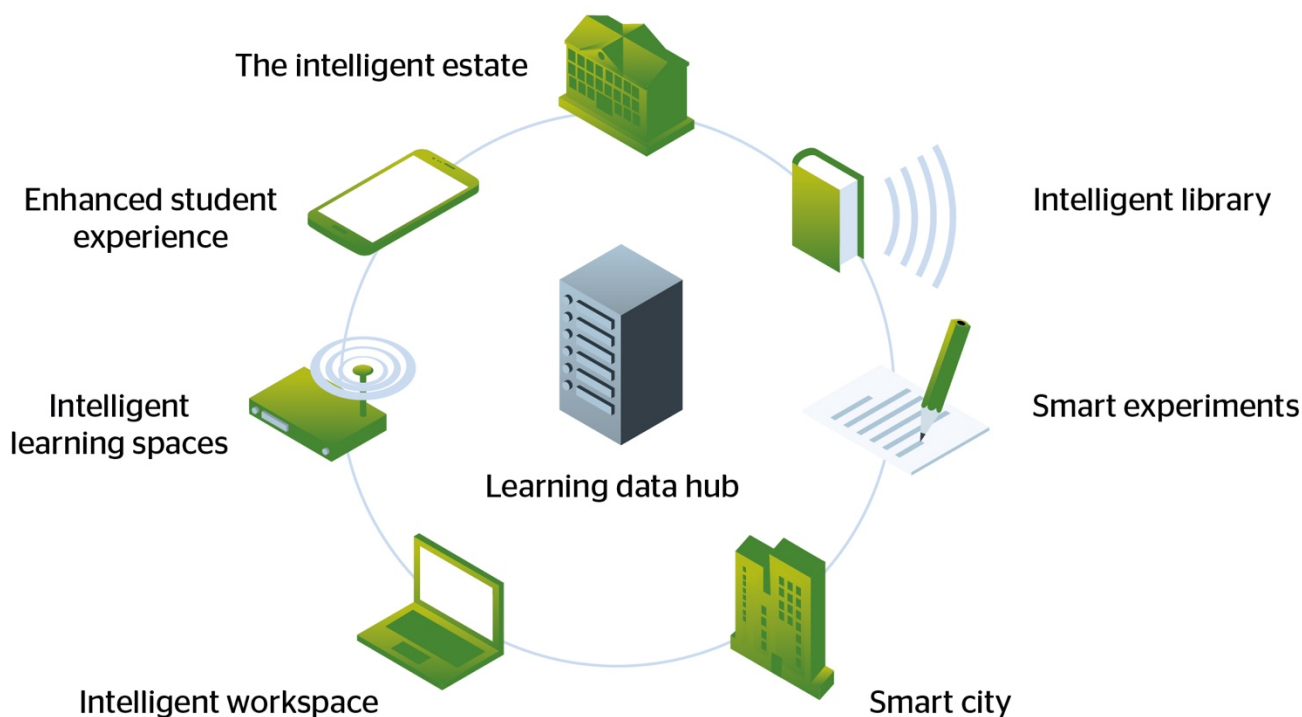
The current landscape

Across the UK universities and colleges are making progress in the many different facets of the intelligent campus space. There are universities who are integrating their smart campuses into the smart city initiatives that are popping up across the country.

Airports are already using Wayfinding to help passengers make quick access to the right gate in time, and there are educational versions of Wayfinding which will help students to get to the right room for the right lesson at the right time.

As Wi-Fi becomes ubiquitous across university and college campuses, many IT teams are using wireless technologies to track devices as they move across campus, as well as finding out which areas of the campus are troublesome for wireless devices or where there are too many devices for the wireless network routers to cope with.

Some universities and colleges are using tools such as Google Maps to provide a better experience for their students as they navigate their campuses. Combined with applications such as Street View, it can make what for many could be a daunting experience, easier and friendlier.

Space within educational institutions is always at a premium and having a clear understanding of the utilisation of space will ensure that not only more efficient use can be made of existing spaces but ensure space rationalisation has a minimal impact. Ensuring those spaces are fit for purpose and are healthy environments for learners and staff, many Estates departments are fitting sensors measuring CO_2 levels, movement, temperature and luminary levels. They use the data from these sensors to make changes to those spaces, some using smart technologies to do this automatically.

Some universities and colleges are using chatbots to facilitate student support and general queries. Integrating a chatbot interface with the multiple systems that universities and colleges have is a real challenge.

Experimental use of facial recognition for attendance as well as early work on emotional recognition for engagement has demonstrated the potential of such technologies, but there have been some ethical concerns over the algorithms and if they really do tell us a true picture.

Across the UK, many universities and colleges are researching, developing, designing, and delivering many different tools and services in the Intelligent Campus space, we cover many of these in this guide. However, what is apparent that most of these are narrow focused and closed systems. Combing data from these various sources could offer new insights and opportunities.

The role for Jisc is to build on our existing work on Learning Analytics. We'll extend the learning data hub to enable data to be gathered in from physical places and from systems that record and monitor space and equipment usage, timetabling and other activities. We know that making timely interventions will enable students to learn more effectively and ensure that the organisation is running efficiently – but this is only the start. Longer-term the possibilities for the intelligent campus project are practically limitless.

Background

The bus arrived at the campus and Leda got off, she checked her app and started to walk to her first lecture. As she passed one of the campus coffee shops she was sent a notification that three of her friends from the course were in there, so she checked the time, she had the time, popped in and found her friends. Her app let her know that she had enough loyalty points for a free coffee, well why not, Leda thought to herself, she could check if there were any additional resources for the lectures today.

The term intelligent campus is becoming more popular, but what does it mean? How can a campus be intelligent, and is it achievable or desirable?

Intelligence

To be intelligent is often defined formally as having the ability to learn, understand and make judgements about something[i] or to be able to acquire and apply knowledge and skills[ii]. However, definitions exist that are specifically in the context of computers and machines, such as "able to vary its state or action in response to varying situations and past experience"[iii].

The field of artificial intelligence (AI) is relevant here, which aims to study the extent to which machines and computers can be developed with aspects of intelligence. As general intelligence is a rather complex concept to tie down, AI helpfully breaks it down into a series of central problems (or goals) - including reasoning, knowledge, planning, learning, natural language processing (communication), perception and the ability to move and manipulate objects[iv].

In understanding what an intelligent campus is (or could be), these AI topics are a useful starting point to describe, evaluate or even design "intelligent" actions or devices.

Perception and action

Perception is a good place to start, with the use of sensors for measuring changes such as temperature or motion and more complex devices such as cameras or GPS enabled equipment.

Data from such sensors could combine with knowledge about the environment (objects, concepts, relations) and lead to reasoning - logical deductions from the data. If we take this a step further, goals could be set, actions taken to adapt the environment, and learning could help the devices improve through experience.

This cycle of perception, reasoning and action is a simplified version of what humans do, and the replication of this, or parts of it, is what AI attempts to do with computers and machines. The extent to which the intelligent campus concept spans these different stages will be something discussed as we explore the topic further.

Central to this are several things, including data, devices and connectivity. If we have devices with sensors that can collect data, we connect them together to enable the data to be transmitted and shared, and then process the data in some way.

The Internet of Things (IoT)

Current everyday devices such as mobile phones can collect data on various aspects of activity including location. Mobile phones also have connectivity, through the telecommunications network or wifi through to the internet.

In fact, not only are mobile devices connected to the internet, but many other common devices, from webcams and printers to central heating systems and baby monitors within the home. Out on the streets we can see connected vehicles, ticket machines and lighting, and engine maintenance and healthcare in industry and public services. An interesting extension to this is the concept of wearable devices, for example used for health monitoring or fitness applications.

This has become known as the internet of things – a wide variety of devices connected to the internet with the ability to collect and transmit data. This provides the potential to integrate all manner of data and use it in aspects of the intelligence concept for example reasoning or adaptation of the environment.

Data and analytics

Data is all around us, and is the subject of much topical debate, including work on open data, big data, and analytics, not to mention ethical issues including privacy and security.

In many ways the collection of the data is easy, it is when we try to interpret and make sense of it that we hit many of the challenges. Analytics has become a common term used to refer to the identification of patterns and

interpretation of data. However, it can span a wide spectrum of sophistication of usage, from presenting and describing through to developing insight and making predictions.

The act of "pushing" data to an individual or group of individuals may have limited value without an understanding of what the data is and what it might mean. Equally, it is possible to misinterpret data and reach conclusions that are not representing the whole picture.

Becoming smart

So, the concept of intelligent campus hinges on several key points

- The availability of connected devices and sensors
- The ability to collect, store and process data
- An understanding of what the data is and how it can be used
- A set of goals to benefit the recipients in making use of the data

Many would argue that the last of these is crucial in making this a meaningful and useful topic to explore and apply. What is also important is to consider the combination of these aspects together, and not one in isolation, for example having a high-quality network infrastructure is only one part of the jigsaw.

Sometimes the term "smart" is used in the same context to explore what a smart campus is or the use of smart devices. In many ways this is synonymous with intelligent campus, although subtle differences in meaning between the two terms do surface in discussions on the topic. Some technological definitions for example refer to smart sensors that possess the ability to collect and transmit data but lack the reasoning aspects of intelligence. Perhaps the important point here for those attempting to develop smart or intelligent campuses is to see beyond the data and the technical capability to more fully understand the purpose and the benefits or otherwise.

Why would we want an intelligent campus?

As Leda drank her coffee, she reflected on why she had chosen ths university. One of the things that had attracted her was the positive reviews and feedback that had come from existing and previous students on the whole student experience. This positive view of the university had resulted in her putting in an application. She was reminded though of one of the induction sessions where the University had taken the time to discuss the whole concept of the gathering of data, the processing of that data, the what interventions were possible and the importance of consent at all three stages. She did worry about this and wondered if all appropriate mechanisms and security was in place to protect her personal data. As she finished off her coffee, she did think was all this data gathering really necessary?

So far we've looked mostly at the concept of "intelligent". Now it's time to look more at the campus aspect. What is driving the agenda to incorporate some of these technical capabilities into the educational setting, and who benefits?

Institutional drivers

If the campus is more responsive, able to react to changes in the environment and to behaviour of those in it, to adapt and to optimise, what are the implications for universities and colleges?

Potential applications exist in several key areas:

- improving the student experience - responding to student needs, providing timely and relevant information, enhancing learning opportunities
- creating new opportunities for research including cross-disciplinary areas, societal challenges and the management of the research lifecycle
- reducing environmental impact - monitoring energy usage and waste, and adjusting energy to meet needs in real time
- enhancing the physical environment - making it more comfortable or conducive to learning
- maximising use of valuable resources - including rooms and equipment, understanding availability and usage

A combination of drivers may be behind specific initiatives that aim to achieve some of the above benefits.

- the economic context encourages better use of resources
- legal and ethical concerns contribute to environmental objectives
- the learning and research environment is influenced by institutional reputation, competition and educational principles
- challenges of increasing amounts of data used in research and how to collect, organise, report or integrate this data in pursuit of research goals

- last but not least, technological advances make this all possible, and in some cases the technology itself may be a significant influence

Ensuring that the technology is used in support of other strategic aims rather than as an end in itself is important in developing useful initiatives.

The concepts are also frequently explored in collaboration with the local area and services, including transport, not just the campus in isolation. Similar agendas are being pursued in other contexts, in particular the development of "smart cities". Examples of universities trying to work with city wide developments are already taking place, particularly in areas such as transport, energy, health, urban informatics, collaboration with other sectors and the environment. This is a topic we will return to in a later section.

Specific benefits

Whether you are a student, teacher, researcher, manager or providing services to others, the intelligent campus offers the potential to improve effectiveness and efficiency. Realising that potential is more complex, and we will introduce specific examples in a later section to look at how this is achieved in practice but here are a few possible scenarios:

- student recruitment and retention – ensuring new students have the best possible experience upon arrival with timely, relevant information being pushed to the student
- the learner environment, experience and voice – monitoring environmental conditions and the feedback from students
- smart research – creating, structuring and publishing data for the research community
- campus management and cost saving – particularly in efficient use of space and facilities – ensuring facilities are as fully available as possible and that students and researchers are aware of available facilities
- anytime, anywhere learning – using smartphones to provide learning opportunities away from the campus and contextual learning

What the campus does have already is a wealth of connected devices, both user-owned and organisational, reliable and fast networks, established systems, and experience in collecting and organising data. Intelligent campus projects aim to bring together these existing systems and infrastructure with innovative applications to benefits campus users.

What are some of the concerns?

There are several main challenges to effective implementation of intelligent campus projects, centred around the following areas which are explored further in a later section:

- setting relevant goals - understanding what is useful and appropriate
- logistics of collecting and processing data - managing the sheer scale of data that can be generated
- interpreting large amounts of data to inform decisions - concerns about bias or misinterpretation in algorithms leading to inappropriate responses
- safety, security and privacy - such as the appropriateness of monitoring the location of individuals and sharing data
- reliance on technology - user skills, the need for resilience in networks, the danger of removing valuable human input, maintenance of devices and infrastructure
- the impact on people - including unexpected consequences of attempts to influence behaviour
- the need for joined up thinking and action from different departments and services across campus

Learning analytics

Analysing the data has already been identified as crucial to the intelligent campus and has been of interest for some time in the context of learning. Learning analytics is the focus other work[v] aiming to use data about students to make informed decisions particularly in the areas of student satisfaction, retention and attainment. It is seen as having the potential to improve understanding in student performance and interaction with university resources, especially in enabling successful completion.

Analytics can be used in other contexts, for example applying the same analysis of data but in the context of teaching processes to support the work of staff rather than the focus of students with learning analytics. This could be in improving administrative efficiency or supporting and enhancing teaching methods for the design and delivery of education.

Where intelligent campus fits with existing analytics work is to consider the integration of different types of data and more joined up analysis and knowledge. For example, learner data and decisions combined with the wider context of the environment, community and services. This includes data on buildings and facilities, learning spaces and location data to deliver a more efficient campus, and potentially taking this further to improved teaching and curriculum design and personalised and adaptive learning.

With more joined up thinking and collaboration between teaching and learning, IT and estates, the benefits to the individual and organisation are potentially much greater, but also perhaps more complex to deliver.

The learning and student perspective

Leda's phone buzzed, she needed to be at her lecture in ten minutes, however the room was different to the one she was usually in. Leda didn't concern herself with this, as she knew that the phone would direct her to the room quickly and efficiently. What was so great about this, Leda thought to herself, was that the sessions she attended were always in the right kind space. Sometimes her lecturer wanted to do group work and the usual lecture theatre wasn't appropriate, so having that in a more suitable room allowed her and her friends to focus on the learning.

What do learners want that an intelligent campus could help with?

Students care about a number of issues including the quality of teaching and, increasingly, value for money. The perception of quality of teaching for some is related to the number of contact hours, although it is also recognised that independent learning is a crucial skill[vi]. Other concerns raised centre around the level of anxiety of students, including around leaving home, learning in new ways, managing workloads, building new relationships and networks of friends and finding jobs.

Social media and other communication technologies already play a part in connecting students together and allowing communication and collaboration on both social and academic topics, with fellow students, staff and others. What can an intelligent campus do to help?

The potential that intelligent campus offers is to integrate data from different contexts and tools in such a way that the educational environment can respond, perhaps in real time, to issues as they arise, rather than wait for those in difficulties to seek help. Alternatively, to make constructive suggestions or help to make informed choices. In particular, the following characteristics have been identified as ones that smart technologies could help support:

- socialising with others, whether for academic collaboration, social activities or mutual support
- identifying and sharing events and activities
- providing real time contextual information that improves decision making
- raising issues and problems as they arise and linking to support
- moving around the physical environment and accessing facilities easily
- making the physical environment more comfortable and healthy

In short, anything that can make life easier for the student, improve their academic progress, enhance their emotional wellbeing or make the environment more comfortable and attractive would be of benefit. This could range from avoiding queues for lunch or learning in a more appropriate room to choosing the right modules or accessing counselling when needed.

Expectations

In addition, students have expectations about using technology and how and when universities and colleges provide services. This is based in part on their familiarity with devices such as tablets and smartphones, and partly their experience of other organisations and tools that already offer sophisticated services. This could be music or shopping services suggesting what they might like next or knowing which of their friends is attending an event nearby.

Where intelligent campus contributes over and above existing applications on smart handheld devices is the collation of data amongst the student body, including potential segmentation by academic or social group, and integration of this with data about the physical environment and the academic context.

Academic

Questions students may be asking include where is my next lesson, what books would be useful for this topic or when is my tutor free for a chat? Whilst this data may already exist in timetabling apps, shared diaries or reading lists, it is typically not "live". Perhaps the tutor isn't physically in their office at the moment due to a delay - the tutor's location-enabled smartphone may know this, but the student doesn't!

Equally, the seminar may be allocated a room in the timetabling process, but how appropriate a space is it for the specific learning activities at the time? Perhaps this week there are presentations or a group exercise, or even an impromptu guest speaker looking for a interactive discussion, and the room booking assumes a standard classroom. The room next door may be better and is fully booked but at the time not actually being used due to a change. If the class moved next door, how easy is it to notify students who are late?

Can relevant materials be signposted as new topics emerge during the session, automatically added to the references for the module, with their location in the library? Are there resources in different formats that match my learning style preferences? Could references be differentiated by difficulty relating to an individual student's understanding of the topics?

Social

Arriving at a new institution can be disorienting and confusing, virtual campus tours can help or sat-nav guided walks, but can these be integrated with personal timetables and interests? What if a personal digital assistant can tell you this is where your first lecture is, and ask if you have thought about the skiing club, they are meeting now in the cafe? What's on the menu today and what do my friends think of the food?

Connecting with people, interests and activities in a more dynamic, responsive, personalised way could enable the student to integrate into the student community more easily, identify others with shared interests, and highlight opportunities to meet and join in. Equally, data about the student might suggest difficulties and anxieties and lead to suggestions about services of use such as counselling - even make available a live chat instantly.

Looking beyond campus, how do students find out about areas to live, and how do the facilities match their own interests? Information on how to travel to and from campus, when's the next bus and what's the traffic like might already be available online. However, what if we combine this with where are good cycle lanes, are there any spaces in the cycle racks this morning or even express interest in the bus after all and one is dispatched as there are other students also asking for it?

Intelligent campus initiatives are often closely linked with services in the wider community including transport and leisure, and other "smart city" projects. Whilst the focus of this guide is on the campus context, there is much to learn from smart cities and the wider world, and the integration with campus data can help smooth the boundaries between life on and off campus and the local community.

Sometimes institutions assume students don't have concerns about technology, data gathering and processing. These assumptions need to be addressed and covered to ensure that students are fully aware of the reasons for the collection, processing and utilisation of data about them and their movements.

The researcher perspective

Leda has the previous night being talking to her friend Samantha who was a researcher on campus. Samantha who use to complain a lot about access to equipment and workspaces, was talking about how over the last year it was becoming much easier to use a range of equipment and spaces. What Samantha had found was that in the past she had found that certain spaces had been booked months in advance, but when she went there found it was empty and equipment was available that she thought wasn't. Recently the university had implemented an intelligent space and equipment booking system that not only freed up space when being unused but took into account calendar data so if a particular researcher was away at a conference their space and equipment if free, could be made available to other researchers. Samantha was so happy and chuffed that her research was moving along much faster than before.

Students are one of several groups of people using the campus, and others may have some similar interests, whether it be visitors, administrators, managers or lecturers. The need for a comfortable and healthy environment, effective use of rooms and facilities, timely access to relevant information are all common concerns. So what specifically would researchers look for in an intelligent campus?

- communicating and collaborating with other researchers, particularly in support of cross disciplinary challenges
- collection, storing and sharing of data in support of their research
- effective interpretation and presentation of data
- publishing and promoting research outputs
- efficient and effective use of facilities
- streamlining the processes in the research lifecycle
- engaging with businesses and the community to maximise impact

How can intelligent campus help?

How can collecting, integrating and analysing data from different devices help researchers in achieving some of these objectives? Some are very similar to the arguments for learners, for example in relation to facilities or people:

- timetabling and using different workspaces flexibly for research and collaboration
- getting the best use out of specialist and possibly expensive equipment
- knowing who is where - colleagues in the cafe or potential collaborators at the conference or industry partners passing by

Real time information on actual usage or location rather than what was planned could be of benefit. Other potential research applications could include working in more sophisticated ways with data or processes across the research lifecycle.

Data in research

Many research disciplines collect, analyse and interpret data as evidence for testing theories or creating new ones. The availability of different sources and methods for using data open up opportunities that may have been used in specialist fields but could now be more widespread. Potential applications include:

- smart experiments - to what extent can data be self-collecting, self-organising or even self-analysing?
- what changes in the environment can be monitored and reported to identify patterns for research - movement or even behaviour of people around a space that is being observed
- can nearby users be asked to share data from their mobile phone for a real time experiment?
- the creation of experiment zones on campus for people to pass through and interact with
- wearable devices are already used in healthcare applications, are there broader applications?

As an example, Southampton University have given open access to a wide variety of data[vii] from on and around the campus, from location information to the shape of rooms, local transport and food outlets to student statistics. Imagine what combinations of this data could reveal in terms of researching say behavioural patterns, transport usage or eating habits? Nottingham University's Smart Campus - Smart Cities[viii] research area uses data such as this to observe, test and evaluate user behaviours, including intra and inter campus mobility and the smart, green, more efficient movement of people and goods.

Another example is Glasgow University whose smart campus initiative[ix] aims to embed smart technology enabling research and development of areas including new materials, design, sensors and urban informatics, in addition to the areas already identified such as health, transport, energy and the environment.

Whilst the collection of data from different sources is perhaps the most obvious application, cross referencing or interpreting the data could be potentially even more beneficial in terms of achieving real impact from the research. This could lead to attempts to unearth real meaning in the data, in other words looking for the narrative underlying the data. As an example, what if the best anaesthetist had the highest death rate because they were given the most demanding cases? Sophisticated analysis is already conducted by humans and computer applications alike, but the opportunity with "smart" research could be in linking data sets together in real time, even ones that are seemingly unrelated, to discover new insights. As with all research, confidence in the ethics is crucial, with robust algorithms and awareness of potential bias or misinterpretation.

The research lifecycle

Streamlining processes and having more efficient and effective access to timely and relevant information is another key feature. For research this could include:

- harnessing and sharing ideas for new research and collaboration
- links with the open science agenda - making data and research outputs publicly accessible

- real-time, on demand access to other professional services providing expertise on grants and contracts or commercialisation and impact such as through a chat bot or connecting to live online help
- access to marketplaces to rapidly test prototypes and innovations
- links to crowd sourced funding for conducting popular research or commercialising it
- hosting flexible and responsive conferences with live research

Although in its infancy, researchers are beginning to explore the potential offered by intelligent campus concepts. For now this is primarily in the scope of collecting and using data in research, however, the application of these same principles in streamlining and enhancing the processes underlying the research lifecycle are an obvious next step.
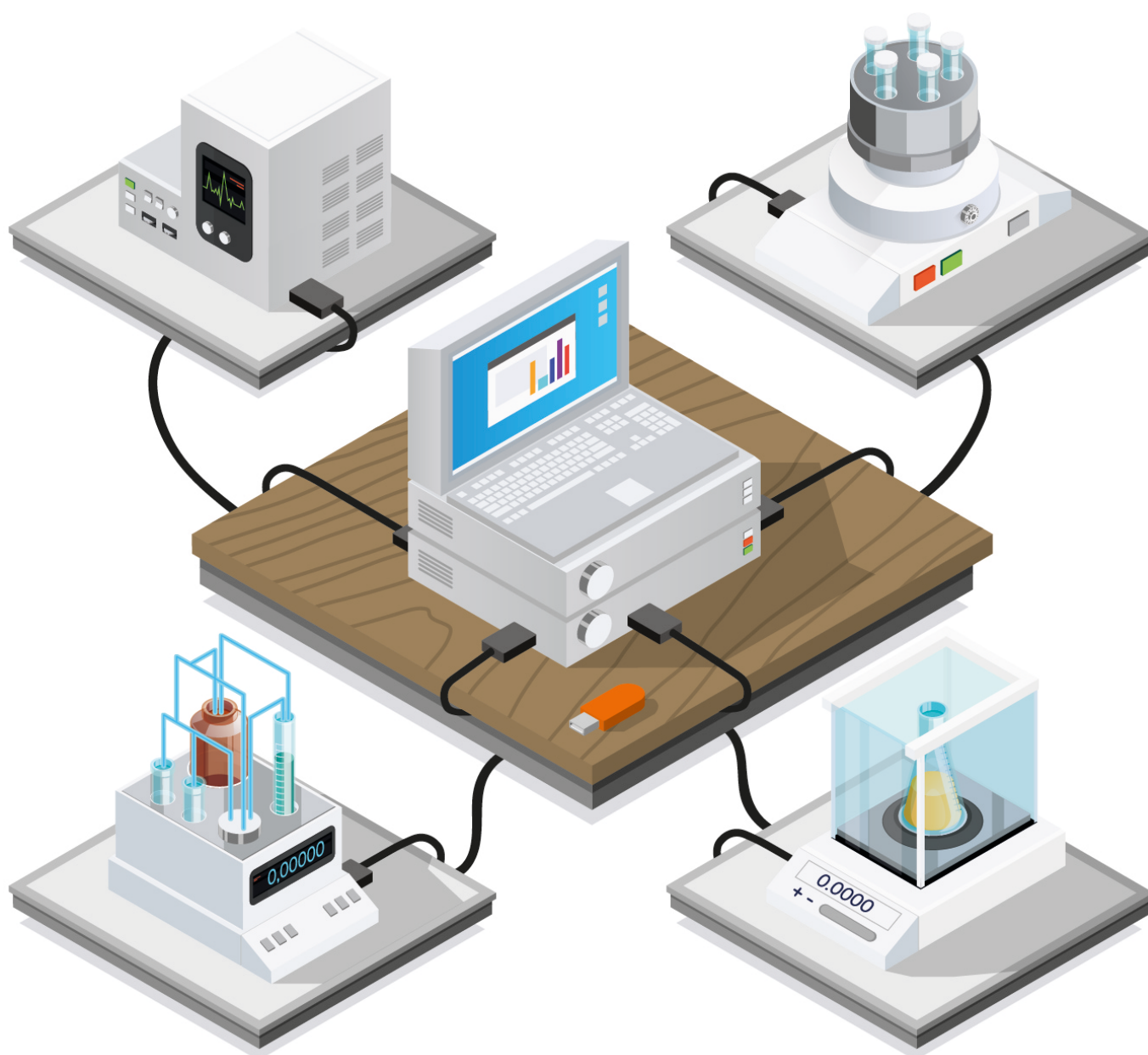
Making the campus smart

As Leda walked around the campus she noticed that there was a lot of devices attached to ceilings and walls. She recognised the CCTV style cameras, though some looked more like speed cameras with some kind of sensor. She had also seen devices with lights in the classrooms and the lecture theatres. Leda made her way to her next session, she used the Wayfinding app on her phone as she knew due to building work on the campus, her usual route was closed. The app would give her the fastest route to get there. As she walked into her seminar room she touched her RFID enabled smartphone to the touchpad by the door. This registered her attendance, but the app recognising her location, started to download the resources for the seminar to her phone and registered her device for the polling and audience response system. Leda found the process much more transparent than being given a clicker. She liked being able to use a single device, her phone for all her smart campus interactions, rather than using a range of devices, cards and equipment to do so.

From the perspective of those managing the campus and the various functions and services operated within it, the intelligent campus has much to offer. In addition to the specific needs of learners and researchers, wider issues are relevant to all campus users, including visitors and professional services staff. The latter in fact are key to supporting and implementing some of the applications of the intelligent campus. Examples of this include:

- Efficient use of energy and resources
- Effective utilisation of facilities
- Managing the movement of and interaction between resources and people within the campus
- Finding cost effective methods for the delivery of campus services

Energy

Energy has been the focus of a number of initiatives, driven by both environmental and cost concerns but also ways to enhance the experience of the campus user. At Georgia Tech[x] for example, they collect data from energy utility systems all over campus, analysing consumption trends and looking for opportunities to become more energy efficient. Not only is data collected and analysed but teams are notified to remedy problems when they arise. They recognise that developing a predictive model of campus energy is complex but using thermal networks and electric grid modelling they aspire to systems that can self-correct without human intervention.

It isn't just about saving money or reducing consumption though, such systems can also help monitor and adjust the working environment to make it more comfortable or conducive to work and learn. One of the themes from Jisc's consultation was the vision "if walls could talk" - a room that is too hot could open a window automatically for example, and what about adjusting noise levels or air quality or improving safety?

Waste

At the other end of the consumption lifecycle is waste. Waste management and recycling are significant challenges for any large organisation, particularly one with a highly mobile and varied user base. Already facilities management services such as those at the University of Nottingham include prioritising bin collection by weight but combining such data with mapping information on facilities for example toilets or social spaces, and effectively routing collection services through campus could streamline the waste management process.


Location and Movement

The movement of vehicles, supplies, and people is another aspect of campus life that could benefit from careful analysis of data from devices. Whether this is reducing queuing time at registration, ensuring food supplies meet demand, or synchronising public transport to special events, many opportunities exist for improving the flow of people and resources to maximise utilisation and minimise waste (including time!).

Location data is currently widely used through smartphone apps and contributes to analysis for example of traffic flow in Google maps. A combination of mapping and location tracking within campus could provide a range of interesting applications including:

- Finding a workstation or a seat in the library and knowing how busy they are
- Providing real time routing for; the most direct route, wheelchair access or combining with activity monitors such as FitBit to hit exercise targets
- Better use of parking facilities
- A better experience for visitors through improving 'signage'

What can turn a smart campus into an intelligent campus is connecting the data from these kinds of activities and combine it with data from other systems and sources and undertaking analytics on the larger data set.
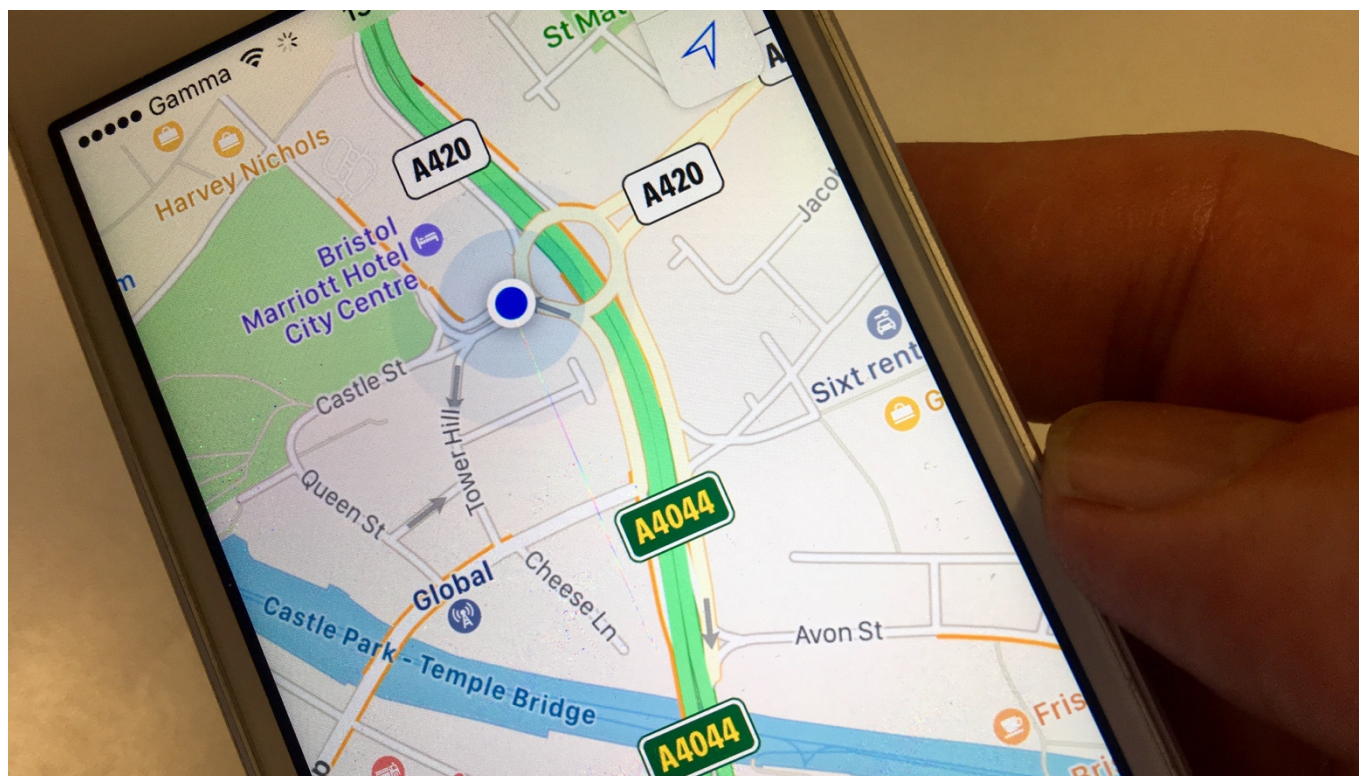
Internal tracking and wayfinding

Colleges and universities can provide internal navigation to students, staff and visitors through online maps and effective external signage. Pinpointing the location of an user allows institutions to use technologies such as Wayfinding. Wayfinding is a system that can be used to guide people through a physical environment and enhance their understanding and experience of the space.

Wayfinding involves four stages:

1. *Orientation* – determining the location of the individual in relation to where they are now and the desired final destination.

2. *Routing decision* – determining the best route to the final destination and selecting that route. This can also take into account the needs of the individual depending on their mobility or other needs

3. *Routing monitoring* – as the individual moves towards the destination, checking that the individual is still heading towards the destination, if there are problems then deciding new a new alternative route.

4. *Destination recognition* is when the destination is recognised and informs the individual.

GPS doesn't work internally, so other technologies need to be implemented to allow for internal geo-positioning. This can be done in many different ways from using geo-locating through the use of wireless routers on the network, to the use of RFID and motion trackers.

Space utilisation

Universities and colleges have a complex portfolio of physical facilities, buildings, equipment and spaces designed for specific purposes or for flexible usage. Room utilisation for example has long been a challenge for timetabling and resource management. We have already noted some learning specific opportunities such as live information on usage of lecture rooms and alternative learning spaces, and equally usage of research equipment could be monitored and displayed.

The use of open plan offices and hot desking is also becoming increasingly common for staff, but many of these processes rely on accurate planning in advance rather than responsiveness and flexibility in real time and may be constrained by specific processes. Examples of more adaptive use of facilities could include interchangeable spaces between teaching, research or public events, usage of space according to time of day or the weather, noise levels or density of people.

Additional benefits could be realised by combining different data sets and communicating to users for example contextual notifications, getting the right information to students and staff at the right time. Not only could you look up where there is a workstation free, but your smartphone could indicate one nearest to you as you move through campus, assess how many other people are heading that way, check the noise levels and find you the quickest route there.

Ethics

When Leda had started her degree programme she had been concerned about how data on her was being gathered, processed and acted upon. It was apparent from the start that her journey through the university, both academically and physically would be tracked. She was happy though that the University had published a guide for students on the ethical use of data. She was aware of what data she had to provide and other data about her for which she had a choice on whether it was collected or not. Leda with her friends had been looking at the open algorithms the University used and had been playing with some of them to see if there were any interesting insights into the way her and her friends interacted with the university systems and the campus.

Ethics (along with security) are perhaps the biggest concerns of campus users when aspects of the intelligent campus are discussed.

Fears and concerns

The collection and interpretation of data from a wide variety of sources understandably raises some concerns about the appropriateness of data collection and usage.

Some campus users will be sceptical of the value of some of the potential benefits and applications of the intelligent campus. They will quite reasonably be protective of their personal data, be conscious of security, and wary of misinterpretation. Even in an age where sharing of data on an app is commonplace, and scant attention is paid by users to the extent of this sharing, the fears and concerns of individuals should not be underestimated nor dismissed.

This can be considered in a number of key areas:

- Awareness and control of one's own data and its usage
- Respecting individual privacy
- Appropriate interpretation and decision making
- Clear and transparent processes and policies

Using data and analytics is likely to involve the introduction of new devices and systems and changes to policies and processes. Different types of data may be collected involving individuals and groups and their activities, analysis will be undertaken, decisions reached, and interventions made. As well as the positive benefits this may lead to, there is scope for misinterpretation and misuse leading to negative consequences. There is a responsibility on those designing and implementing applications within the intelligent campus to provide reassurance and effective management.

Questions that campus users may have include

- What data is being collected about me?
- Why is it being collected?
- What will the data be used for?
- How is it being interpreted?
- What actions will be taken as a result?
- Who will see the data?
- Can I control what data is collected and shared?

Specific concerns include the notion of being tracked, that the location of an individual is being monitored and the information used in some way to mount a form of surveillance or checking up on people. The original intention might have an appropriate justification, such as logging attendance or clocking in for work, but what other interpretations are being made - how many breaks you have, or how often you go to the toilet! Whether these are intended uses or not, the collection of the data raises concerns about potential usage and how the data might be used.

Jisc have produced a code of practice for learning analytics, which covers in some depth a number of the topics referred to below and is a useful reference for those wanting to explore further.

Personal data and privacy

Personal data is defined by the data protection act as data relating to a living individual who can be identified. This isn't just identification from the data itself, but from other data or information that could be in the possession of the "data controller". Individuals also have the right to be able to correct inaccurate personal data recorded about them.

The new GDPR (General Data Protection Regulation) will bring in sweeping change to the current Data Protection Act 1998 and universities and colleges should ensure that they are prepared for the key changes which will be brought about by the GDPR.[xi]

The main changes that GDPR brings which means institutions will need to reflect on when implementing or enhancing an existing intelligent campus are:

- Accountability measures
- Privacy by default or design
- Data protection impact assessments
- Higher standards for valid consent
- Statutory liability for processors
- Mandatory breach notification 72 hours (where feasible
- Increased data subject rights
- Greater transparency around data processing
- Profiling
- Minimum mandatory contractual provisions in data processing clauses/ contracts
- Tighter rules on international transfers

Some of the examples of data used in intelligent campus activities might be thought of as not personal. However with the combination of different types of data from different sources, it becomes potentially easier to identify individuals, for example precise location and user behaviour. Anonymised data once aggregated can lead to better understanding of user behaviour and the management of facilities, but also potentially reduce privacy.

For example, a room is booked by a student society, the membership of that society is known, movement of anonymous individuals show a group congregating in that room, attendance records show who is present at lectures that day, and slowly a picture is built up of who is doing what and when. One key point is that access to data and the analysis of data should be limited to those who have a legitimate need to view them. This leads to a number of other policy and procedural issues that need to be addressed, some of which are covered in the following sections.

Responsibility

Universities generally have policies relating to the use of data but are they sufficient to cover the increasing complexity of different data types, sources and integration?

This includes the notion of responsibility, that can be considered in a number of areas across legal and ethical concerns. The different elements of collection, anonymisation, analysis and decision-making need clear and specific responsibility assigned, as well as covering the objectives and intentions, interventions to be carried out, retention and stewardship of data. This could involve staff and services from different parts of the university, including IT, student services, legal and policy representatives. In addition, consultation of those potentially impacted by the practices should be undertaken at all stages of the design and implementation.

Transparency, consent and sharing

The objectives and processes involved in collecting and analysing data should be made clear to the individuals involved. Obtaining consent from individuals to use data is critical and three aspects of consent can be considered in the context of the intelligent campus and analytics:

Gathering - how the data is collected or recorded

Processing - concerning the interpretation of the data

Actioning - making interventions on the basis of the decisions reached

Having appropriate policies and effective implementation in these three different aspects is important. This is to ensure individuals are fully aware of what data is being collected and used and have made informed decisions on that usage.

As an example of these different levels, if anonymised data is collected generally about the movement of people, this might fall into consent for "gathering". If the location of a specific individual is being collected and this is being used to determine behaviour, then this would require consent under the "processing" aspect. If the result

of the interpretation is that contextual notifications or other information are sent to an individual, then consent would be expected under "actioning".

Another aspect of sharing and consent relates to the current approaches to apps on devices such as smartphones. Users of these devices readily accept sharing requirements when they install apps and accept the terms. This may include the sharing of that data with third parties for example for advertising.

Typically, this includes location but can also be your email address, contacts, search terms or even access to your camera. Specific examples include health apps collecting sensitive information about a person's health, diet and activities and social media apps holding information on interactions and social groups. However, many apps also ask for permissions to access other data that can be seemingly unrelated to the purpose of the app.

Why are users seemingly relaxed about accepting various sharing conditions for apps but concerned about issues like surveillance when it is their university? One partial reason could be lack of awareness of exactly what is being shared and why. Another could be the perceived impact of such sharing. The university might be seen to play a more significant part in their life than a seemingly faceless company collecting information for more general use or advertising. For example, being at university can be a life defining period for students, with an impact on future career and social groups. Equally, for staff, being tracked or monitored by your employer might have perceived consequences for their career prospects, performance reviews or compliance with policies and procedures.

Universities could choose to add clauses to their terms and conditions, such that users accept these terms as part of wider acceptance of usage policies. However, users may tick the box to agree without really being aware of the implications and having technically received their consent doesn't alleviate fears and concerns or avoid problems arising later.

Educating users to be more aware of what data they are sharing, or to switch permissions off when not needed is important. Alongside this is transparency from apps and services in how they promote their facilities. Educating students to be more aware of security and privacy would be helpful regardless of whether the data is collected by the university itself or other parties. This could be considered as an aspect of digital literacy - the competencies needed to participate effectively in a digital knowledge society.

Interpretation and validity

There are reasonable concerns over the appropriateness of linking data together and drawing conclusions about related factors from this information. For example, consider a future scenario - institutional knowledge about a student's learning, attendance and progress, combined with details on their current finances held by them personally might suggest possible difficulties or anxieties and lead to suggestions about services such as counselling - even make available a live chat instantly.

This may be seen as a valuable intervention, but also relies on interpretation of data and reaching conclusions that may be flawed, not to mention access to sensitive data. Particular care needs to be taken in designing algorithms that make interpretations such that the decisions are free from bias or assumptions and are reliable and appropriate. As we move further into "intelligence", and algorithms that can learn and adapt, we need to be

aware of the potential of data-driven algorithms to learn our prejudices and lead to undesirable and even illegal outcomes such as discrimination.

Other examples include the use of facial recognition to assess emotions and link this to understanding or anxieties. However, reading facial expressions is complex, for example a frown could mean confusion or concentration, and we would need to be confident that such an application was based on reliable evidence of success.

Data collection and processing should be subject to the same measures of quality, validity and robustness that might be applied to research for example. This includes identifying inaccuracies, awareness of incomplete data, care with choice of data sources and appropriate correlations of data sets. Considerations of validity, usefulness and appropriateness would also apply to the algorithms and interventions.

Having rigorous processes across the three phases of gathering, processing and actioning, combined with careful consideration of the concerns of users will help to deliver benefits to users of the intelligent campus.

Security

> *Though Leda had concerns about her personal privacy with all the data gathering happening on campus, her and her friends had noticed a reduction in crime and vandalism. When incidents happened on campus, reaction time from the campus security officers was really fast they could get to the right place much quicker. Leda did think it was all a bit Big Brother but did feel safer.*

Benefits

Features of the intelligent campus offer the potential to enhance security for users and the physical assets of the campus. CCTV is nothing new, but with remote control of cameras, linked with real time notifications to security staff, availability of digital floor plans and control of alarms, locks and access systems, a wide range of new benefits for campus users could become available. This could include facilities for individuals such as mobile panic buttons and alerting systems. Issues such as bullying (including cyberbullying) and harassment, criminal activity or emergencies could all potentially be dealt with by harnessing such technology. The range of emergencies that could be handled more effectively include natural disasters, medical emergencies or violent attacks. Monitoring where people are and their movement, providing information and assisting the emergency services have been shown to be of value in a number of incidents in the US. However, ethical issues including privacy and consent are also critical, as covered in the previous section.

Device security

The proliferation of devices connected through the internet, including embedded and wearable devices, is often referred to as the internet of things (IoT). It has led to concerns about vulnerability to hacking and other attacks, and the safety of data collected. The devices are typically specialised for a particular function (eg a webcam) and don't have the sophisticated software available to desktop or mobile computers. In many cases this means they are produced with the minimum functionality to perform their task, and security features can often be omitted, leaving them vulnerable to attack. Furthermore, they may run only with the factory installed software and be difficult to "patch" with updated features.

This may be a problem that is only corrected over time as device manufacturers and their users become more aware of the dangers and are willing to pay the extra cost for added safety. Device users can currently check more carefully about what the device can and can't do, what can be accessed and by whom, and whether any updates are available. The local IT department may offer guidance and support on how best to use devices for effective integration with the campus infrastructure.

It may be appropriate to also consider what level of security is needed, depending on the type of data and the criticality of the device. For example, what consequences are there if the temperature sensor of a building is hacked? This may reveal information about the actual temperature, but it is probably more serious if the controls

of the heating system were compromised. It may be more important to focus on securing the processing and integrating of the data and the subsequent decisions and actions taken from interpreting the data.

Infrastructure

Jisc provides guidance and services to universities and colleges on cyber security and managing IT networks safely, including key issues of relevance to the intelligent campus. These include:

- Viruses and hacking - of particular concern with the proliferation of devices and the Internet of Things
- Authentication - ensuring the right people have access to the right data in line with appropriate transparency and consent
- Encryption - making the transmission of data between devices and systems safe from unauthorised access and supporting the integrity of that data
- Secure storage - protecting the gathered data in a safe location
- Backups and data loss prevention - systems and procedures to guard against loss or damage of data

All of the above need careful consideration in effectively implementing systems and applications to support the intelligent campus features. In addition, the wider IT and network infrastructure needs to be fit for purpose and able to support the intended applications. This may include having a reliable network of sufficient bandwidth to allow intelligent solutions and interoperability of systems and services to support the integration and exchange of data.

Security and ethics are perhaps the biggest concerns of campus users when aspects of the intelligent campus are discussed. Approaching both aspects with careful consideration of the limitations and opportunities of interconnected smart devices is important. In addition, a full appreciation of those impacted is critical to ensure that design and implementation of new applications is carried out for maximum impact.

Smart city

Leda was sitting in the library reading through the book she had borrowed, her phone buzzed with a notification, her bus home was due shortly and if she left now, she would be able to catch it. Leda really liked this as though there was a bus timetable, the realities of traffic and weather meant that the buses weren't always on time. The bus company used GPS to identify the exact location of their buses and this data could then be used by the university app to help learners catch their buses on time. One of the reasons Leda liked this was that it was raining, and it saved having to stand in the rain for too long. As Leda sat down in the bus, her phone buzzed again, as she had walked from the library to the bus stop, the phone had downloaded an interesting podcast related to the lecture she had been to ready for her to listen on the journey home.

The concept of the intelligent campus doesn't exist in isolation and parallels can be seen with the various initiatives around "smart cities". Not only is there interest in applying similar ideas within the communities and spaces outside of campus, but the integration of smart cities with the intelligent campus offers many interesting opportunities.

The smart city may focus on key areas such as delivering services effectively, enhancing lives and improving the environment. Drivers include increasing urbanisation and population density, financial pressures, regulatory requirements and the complexities of managing areas of high population. The latter include issues around housing, employment, crime, pollution and transport. In addition, there are increasing expectations from the public who are used to instant personalised information and 24 hour access to services through mobile devices.

The intended results would be healthier communities, more efficient use of resources and an enabling infrastructure supporting both businesses and the public. Many of these can be seen to be similar to objectives for the intelligent campus.

Smart city examples

Smart applications in towns and cities typically include energy and the environment, health, transport and the movement of people. Examples include:

- Smart traffic sensors helping ease congestion by adjusting signals
- Location sensors tracking emergency vehicles or public transport and reporting how close they are to you
- Weather sensors identifying where floods will occur following severe storms and notifying residents to evacuate
- Monitoring where people congregate at different times of the day, the impact on services and the environmental conditions
- Switching lights or heating on and off in public buildings depending on usage to optimise energy use
- A smart water network that detects and reports leaks as they occur

As with campus examples, the combination and integration of different data can yield particularly interesting insights and lead to innovative interventions. One example would be to combine data on population growth with historic data on traffic and trends on changes in transportation such as cycling. Used to explore new transportation routes, this data could lead to monitoring and adjusting the traffic controls in real time to achieve optimum flow.

Linking the campus

Where the links between city and campus are strongest are when a more holistic view of people and facilities is taken. Such a view understands that individuals are at the same time members of a community, residents in a neighbourhood, students/staff at a university and participants in social groups and activities across the boundaries. Sharing of data across the campus and local area can enable both efficient use of resources and better services for users.

The environment is a common interest area. Businesses, educational bodies and public agencies all have legal, financial and ethical responsibilities to use energy more efficiently. Monitoring and adjusting energy use in response to demands and conditions is similar both within and outside the campus. By joining forces, local agencies and university managers can share expertise, contribute to common goals and coordinate at the interfaces of the campus and local community.

Transport is an obvious link between the local area and the campus, allowing students and staff to move more easily to and from and around the campus. Key transport routes into the campus may already be identified and prioritised, for example expanding cycles lanes from student accommodation areas. Public transport routes and times could be combined with information on the timetabling and actual attendance of campus activities, both within and outside the curriculum. This can enable either real time information on the next available and closest bus to take you home after lectures, or even facilitate special services. After graduation a conference or a sporting fixture for example, shuttle buses or shared taxis could be provided in response to demand by individuals expressing interest or booking through their mobile devices.

Research into smart cities

Much of the work being done around smart cities is research involving universities. Numerous universities in the UK and abroad are conducting experiments around urban design, energy and the environment, transport and health. Effectively a "mini city", with aspects of its own infrastructure, housing and transport, the campus can act as a test bed for larger scale activities. In addition, the skills and expertise of researchers across various disciplines can be brought together to address societal challenges.

Glasgow's 'Future City Demonstrator' involves the University of Strathclyde's Institute for Future Cities. Creating the City Observatory, data is being used to develop innovative approaches in areas such as crime, economics and

sustainability. Examples include open data integrated to plot a visualisation of geographical distribution of disease across Glasgow such as:

- Hospital admissions for heart disease and strokes
- New registration of lung cancer patients
- Deprivation data

The Institute for Sustainability at Newcastle University is leading a Smart Grid project looking at how sources of power can be managed more effectively. This aims to improve storage, network configurability, responsiveness to demand and resilience to failures. It does this by linking together components that gather information about the network, informing switching decisions and electricity distribution.

'Bristol Is Open' is a joint venture between the University of Bristol and Bristol City Council. Sensors supply information about energy, air quality and traffic flows for example and these are available for developers to build and test applications. These applications range from congestion management and waste management, to new forms of e-democracy, on-street digital games and driverless cars.

Moving it forward

Smart city and intelligent campus designers have common challenges. Data collection and processing in silos is of limited benefit and the integration of different departments and functions is one of the keys to delivering value from this concept. This cross-functional approach is known to be challenging and cuts across different systems, processes and cultures. However, the benefits are clear - more efficient use of limited resources, streamlined processes and increased value in services provided.

Whilst the focus initially may seen to be around new technologies, in practice the real effort is in achieving human coordination and collaboration. In addition, effective management of the ethical issues is crucial to making the intelligent campus as success. Universities however are well placed to understand and implement key aspects of the intelligent campus - cutting edge innovation, cross-disciplinary working, rigorous processes, a sharing and collaborative culture and a concern for ethical standards.

Being at the forefront of innovative approaches to smart technology and applications around the digital experience can strengthen the reputation of universities. The societal impact of research is increasingly important, and this can combine with delivering direct benefits to students and other campus users.

Summary

As Leda settled down for the evening, she reflected on her day. What kind of day would have it been without her phone, without it connected to the different services on campus, the way it worked in a smart or even intelligent way. It was making her whole experience better, she could focus on her studies and spend a lot less time trying to find rooms. The university called it the intelligent campus, in Leda's view it was more than that, it was a campus that improved the whole student experience. Well for her it did.

The role for Jisc in the Intelligent Campus space is to build on our existing work on Learning Analytics. By understanding the different data sources available and what data they can gather, we can then extend the learning data hub to enable data to be gathered in from a range of physical places and from systems that record and monitor space and equipment usage, timetabling and other activities.

We know that making timely interventions can improve the student experience, it enables students to learn more effectively and ensure that the organisation is running efficiently – but this is only the start. Longer-term the possibilities for the intelligent campus project can only be imagined.

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[i] Cambridge http://dictionary.cambridge.org/dictionary/english/intelligence
[ii] Oxford https://en.oxforddictionaries.com/definition/intelligent
[iii] Oxford https://en.oxforddictionaries.com/definition/intelligent
[iv] https://en.wikipedia.org/wiki/Artificial_intelligence
[v] https://www.jisc.ac.uk/rd/projects/effective-learning-analytics
[vi] HEPI-HEA Student Academic Experience Survey http://www.hepi.ac.uk/wp-content/uploads/2016/06/Student-Academic-Experience-Survey-2016.pdf
[vii] http://data.southampton.ac.uk/datasets.html
[viii] http://www.nottingham.ac.uk/research/groups/human-factors-research-group/research/smart-campus-smart-cities/index.aspx
[ix] http://www.gla.ac.uk/about/campus/overview/smartcampus/
[x] http://www.news.gatech.edu/2015/05/26/tech's-campus-gets-'smart'
[xi] Preparing for the General Data Protection Regulation (GDPR) https://www.jisc.ac.uk/guides/preparing-for-the-general-data-protection-regulation-gdpr