Joona Lehto

# BUILDING A SMART CAMPUS APPLICATION – USAGE, PERCEPTIONS, AND IDEAS IN THE AGE OF AI AND HYBRID LEARNING

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Viimeisen vuosikymmenen aikana älykampuksen konsepti on saanut osakseen merkittävää huomiota akateemisessa maailmassa. Käytännössä konseptilla tarkoitetaan arvokkaiden, kampusarjen eri osa-alueisiin integroituvien, ja uusiin teknologioihin pohjautuvien palveluiden luomista ja hyödyntämistä kampuksella. Yliopistot ympäri maailmaa ovat käynnistäneet aloitteita muuttaakseen kampuksensa älykampuksiksi, ja aiheesta on julkaistu merkittävää tutkimusta. Tämä pro gradu -tutkielma tarkastelee aihetta älykampuksen mobiilisovellusten näkökulmasta, hyödyntäen kirjallisuuskatsausta ja empiiristä tapaustutkimusta erään älykampuksen mobiilisovelluksen käyttäjäkokemuksista. Tutkimuksen päätavoitteena on rakentaa ymmärrystä siitä, mitkä ominaisuudet ja teknologiat ovat yleisimmin käytössä älykampuksen mobiilisovelluksissa, onko käyttäjillä kiinnostusta integroida tekoälyä tällaisiin sovelluksiin, ja mihin kampuselämän osa-alueisiin sovellusten todellinen käyttö kohdistuu. Tulokset osoittavat, että älykkään elämisen ja oppimisen alueet hallitsevat älykampus-mobiilisovellusten käyttöä ja ominaisuuksia – sovellukset tukevat merkittävästi sekä päivittäistä elämää, että oppimiseen liittyviä toimintoja fyysisellä kampuksella. Tutkimuksessa havaittiin myös, että laaja joukko teknologioita tukee näiden sovellusten ominaisuuksia. Näistä teknologioista yleisimpiä ovat mobiili-, datan laskenta & tallennus sekä IoT-teknologiat. Tekoälyn käyttö on tällä hetkellä vähäisempää, mutta sillä nähdään olevan merkittävää tulevaisuuden potentiaalia. Lisäksi havaittiin, että tietyt yleiset ominaisuudet voivat parantaa älykampuksen mobiilisovellusten hyödyllisyyttä ja kätevyyttä. Näiden tulosten myötä tämä tutkimus tuottaa teoreettista hyötyä esittämällä käyttäjäkeskeisen näkökulman siihen, mikä rooli mobiilisovelluksilla yleensä on älykampuksen ja sen sovellusalueiden kontekstissa. Käytännön hyötynä tämä tutkimus tarjoaa ideoita ja suosituksia, jotka voivat auttaa oppilaitoksia toteuttamaan ja parantamaan omia mobiilisovelluksiaan.

Asiasanat: Älykampus, mobiilisovellukset, teknologian käyttö, käsitykset, kehitysideat, tekoäly, esineiden internet, mobiilisovellukset

## ABSTRACT

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During the past decade, the concept of a smart campus has gained significant attention in the academic community. Essentially, the concept of a smart campus is about utilization of novel technology to build valuable services, that integrate to all aspects of the life on campus. Universities around the world have created initiatives to transform their campuses into smart ones, and significant research has been published on the topic. Through a literature review of this existing research, and an empirical case study focusing on user experiences of a particular smart campus mobile application through a theory of application domains, this master's thesis explores the topic from the viewpoint of smart campus mobile applications. The main goals of this research are to build an understanding of which features and technologies are commonly utilized in support of such mobile applications, whether there's interest in integrating artificial intelligence to such applications, and which domains of life on campus the applications' usage serves in practice. The results indicate the domains of Smart Living and Learning dominate the usage and features of smart campus mobile applications, with the applications taking a major role in supporting both daily life, and learning-related activities on physical campus. It was also found that wide variety of technologies are utilized to support the features of these applications, with mobile, data computing & storage, and IoT technology being most common, with artificial intelligence seeing less usage, but significant future potential. Additionally, it was found that several general qualities can increase usefulness and convenience of smart campus mobile applications. With these results, this research provides a theoretical contribution by presenting user-centric viewpoint into what role mobile applications usually play in the context of the smart campus and its application domains. As a practical contribution, this research provides ideas and recommendations that can help educational institutions implement and improve their own mobile applications.

Keywords: smart campus, mobile applications, technology usage, development ideas, artificial intelligence, internet of things, mobile applications

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# 1 INTRODUCTION

During the past decade, the quality of smartness has been attached to many concepts of human life, ranging from smart devices to smart buildings, and even entire smart cities (Zhang et al., 2022). Somewhere between the smart building and city lies the related concept of a smart university campus. Despite significant research attention during past years, there is no universally accepted single definition of the concept (Chagnon-Lessard et al., 2021). However, based on a synthesis of previous research, smart campus can be seen as application of services that are perceived innovative and valuable by campus stakeholders, are supported by advanced technology, and integrate to all domains of the campus life in an interconnected manner, including secondary and core business processes and stakeholder's daily activities, both in physical and virtual, remote dimensions of the campus. By utilizing terminology defined by Zhang et al (2022) in their literature review, this study refers to these different domains of campus life as application domains, as different services of a smart campus are created and applied in support of these domains. Building smart campus services requires use of various technologies, which Zhang et al (2022) and this study similarly observe through concept of technology domains.

Like cities with their smart city initiatives, universities around the world have created initiatives to build smart campuses. In Finland among them is the University of Jyväskylä (JYU), with a campus hosting around 14 000 degree students, and 3000 staff, as well as over 20 000 non-degree students through open university (JYU, 2021). The university created a smart campus initiative as a part of its digital development program in year 2018. Since then, the university has successfully implemented many services as part of the initiative. From and end-user perspective, perhaps the most visible of them is the MyJYU smart campus mobile application, which entered service in spring 2019 on Android and iOS platforms, with the primary aim of connecting and augmenting physical campus resources (Lumor et al., 2020). Essentially, the application can be seen as a smart campus assistant, through which, students and staff get easy access to functionality useful in daily life, such as finding services, checking calendar events, lunch menu, map, and reserving spaces for self-study. The application is in active development, and available to staff, students, and visitors alike.

This research takes the form of a case study focusing on the MyJYU application, exploring its use and features, as well as perceptions and development ideas for new features through the lens of existing smart campus research. The central goal of the research is to identify which areas of life in the campus are currently most supported by the features and use of the application, and which areas users want supported in the future. As different technologies are needed to implement the features, also technology used in support of smart campus applications is explored, with special emphasis on potential of artificial intelligence, as recent advances in large language models (LLM's) are already transforming education (Gill et al., 2024), and being a leader in AI utilization is a central goal of university's digital development program. By exploring these topics, this research can provide the theoretical contribution of augmenting previous, limited research on multi-feature smart campus mobile applications, as well as providing a new, up-to-date view on top of previous studies on MyJYU, such as the study by Lumor et al (2020). As a practical contribution, this research can help university management and development services guide and prioritize future development of the application, as well as evaluating implementation of supporting technologies, including AI. With the above goals in mind, the following research questions were defined to guide the research.

1. Which applications domains identified in previous research receive most interest in the features of smart campus mobile applications?
2. Which technology domains identified in previous research are most utilized by smart campus mobile applications?
3. What kind of ideas and attitudes do MyJYU application users have towards current and potential future features of the application, including perceptions towards utilization of artificial intelligence as part of the application?

To help answer these questions, a literature review of the concept of smart campus and its mobile applications was conducted utilizing relevant databases such as IEEE Xplore, ACM Digital Library and Scopus. In the first stage, articles containing comprehensive literature reviews were searched using query "Smart campus AND literature review", returning multiple high-quality sources that were utilized to build a general model of smart campus and its domains. After that, research on smart campus mobile applications was searched using query "Smart campus AND mobile application", returning many case studies describing implementation of such mobile applications. To support the third AI-related research question, additional sources were searched on use of AI in educational context, with emphasis on large language models due to its significance as a current trend. Some additional research was also searched to help define related concepts, such as smart cities. The various studies were then compared to the model created through analysis of literature reviews to build an understanding of how smart campus mobile applications are related to its application domains and other technologies, and what potential recent developments in AI might bring to this area. These results were then utilized to support the case study research on MyJYU mobile application, which was conducted using a thematic analysis, with responses from a new student survey, and existing data from an earlier staff workshop utilized as the material.

In the following chapters, this study first discusses the history and various definitions of smart campus through the lens of existing literature, eventually forming its own synthesis of the definitions. After that, the theory of application and technology domains by Zhang et al (2022) is utilized to observe the practical implementations and components of smart campuses in existing literature. This understanding is then utilized to analyze the results of a comprehensive literature review on existing research on smart campus mobile applications. The potential to utilize artificial intelligence is also briefly discussed. The literature review is then followed by a description of the empirical study, including collection of data and thematic analysis as a research method. The actual results of the analysis are then presented, followed by a reflection of the results in relation to existing literature, and finally a conclusion.

# 2 SMART CAMPUS

This chapter discusses the concept of smart campus through the lens of previous literature reviews. Due to the wide variety of definitions and approaches towards the concept in this previous literature, it's necessary to first observe its history and different definitions, and then look at the areas of campus life that smart campus services can be applied to, and what kind of technologies can be used in support of those applications. Following the model defined by Zhang et al (2022), the areas of campus life are referred to as application domains, and supporting technologies are grouped as technology domains. Rather than simply discussing the domains found by Zhang et al (2022), this chapter aims to form a synthesis where the domains are compared and potentially extended by findings from other studies.

## 2.1 History and the Definition

The idea of applying the word "smart" to inanimate physical objects is not a new one, nor is the idea of applying the word into the specific context of a university campus, which at its core can be seen as a place to provide educational services (Zhang et al., 2022). As an example, the study by Ng et al (2010) already noted emerging phenomena of smartification of phones, homes, and buildings, and proposed a model of an intelligent campus ecosystem, where intelligent digital technology is applied in campus context. Furthermore, the study could point to multiple previous research articles mentioning the concept of "smart campus", including a research article examining the creation of a distance learning video conference system (Kaneko et al., 2000), which would appear to be among the oldest scientific articles with the concept mentioned in the title. Despite this history of research, there is still no single universally accepted definition of smart campus (Chagnon-Lessard et al., 2021), as mentioned in the introduction chapter.

According to the literature review by Muhamad et al (2017), the main approaches taken towards defining the concept in previous research were technological, smart city, and organizational process approach. Later comprehensive literature reviews have followed these trends, by linking the concept smart campus to the concept of smart city (Chagnon-Lessard et al., 2021; Zhang et al., 2022), while in case of Zhang et al (2022) also noting the technology-oriented nature of most previous research. Two additional literature reviews by Imbar et al (2020) and Akbar et al (2023) make similar conclusions, with emphasis on technology and smart city terminology.

### 2.1.1 The Smart City Approach

While lacking an universally accepted exact definition, generally the concept of smart city can be defined as a place where efficiency, flexibility and sustainability of traditional networks and services is increased through the use of digital and telecommunication information technology, resulting in benefits for its inhabitants (Mohanty et al., 2016). Based on research by Muhamad et al (2017), the smart city approach can be justified through similarities in challenges faced by cities and campuses. Through this approach, a smart campus can essentially be seen as a small, self-contained city (Muhamad et al., 2017), or a medium level in a scale of smartness ranging from smart homes to cities and entire regions (Chagnon-Lessard et al., 2021), where smart technology is applied in response to the similar challenges faced. While more numerous smart city research can be adapted to smart campus context, it's also notable that a smart campus can be an interesting, more controllable medium-sized environment for piloting technology that could be later adopted in larger scale of cities and regions (Chagnon-Lessard et al., 2021), implying a two-way relationship between these research areas. In addition to its size, the campuses skilled workforce can give it an advantage in innovation compared to entire cities (Malatji, 2017), and its core role as a center of research can make it a good place to test groundbreaking technology (Chagnon-Lessard et al., 2021) It should also be noted that campuses are typically located in cities, and smart education can be seen as one fundamental component of smart city's functions (Mohanty et al., 2016), based on which it can be argued that smart campus can be a central component of a smart city.

### 2.1.2 Technological Approach

Regarding technological approach, Muhamad et al (2017) make an interesting distinction between a digital campus, which involves application of traditional technology, like local area network, online learning materials and isolated systems, and smart campus, where technologies such as internet of things (IoT) and cloud computing create more dynamic interoperable, intelligent systems. From this viewpoint, a smart campus can be seen as a continuum of digitalization in education, where cutting-edge technologies are applied on top of existing technology to provide interoperable, intelligent services. Muhamad et al (2017) argue that eventually this process of applying technology can amount to the formation of an all-encompassing digital nervous system resembling the model defined by Ng et al (2010). However, it can be argued that this prominent, technology-centric approach of building a smart campus has its limits. In existing research, many smart campus studies appear to focus on finding applications to technology, rather than finding solutions to solve central problems and meet stakeholder's needs (Zhang et al., 2022). Just as Zhang et al (2022) emphasize the importance including a human-viewpoint in research for smart campus features, it can be argued that the very definition of smart campus should explain how technology serves the campus, rather than it being merely present.

### 2.1.3 Organizational Process Approach

With the need for human-centricity noted, the third, organizational process approach defined by Muhamad et al (2017) gets closest to this viewpoint by defining the smart campus as an entity that utilizes technology to provide high-quality, efficient, and intelligent services to stakeholders in all aspects of their campus lives. Essentially, this approach captures the need, noted by Zhang et al (2022), to apply technology in a way that produces actual value to campus life, rather than seeing application of technology as the goal itself. Compared to the smart city approach, it can be argued that approaching the definition through this viewpoint can also shine more light into specific needs of smart technology in educational context. A campus might share many difficulties – such as parking, traffic and building management with cities, but also has its own processes created through its purpose of education, innovation and research, which may be enhanced through adaptation of smart solutions (Chagnon-Lessard et al., 2021).

### 2.1.4 The Definition

With common approaches defining smart campus explored, it's now time to examine and synthesize the actual definitions given in earlier comprehensive research. By integrating the three approaches, Muhamad et al (2017) provide a rather lengthy definition, defining smart campus as a university-led effort to provide valuable, dynamic, and user-oriented services that enable many functions and cover a broad aspect of campus life in addition to learning activities, through utilization of information technology that is both advanced and intelligent. Chagnon-Lessard (2021) the other hand don't provide their own definition, but instead observe the concept through features of smart neighborhoods, cities and regions, all of which utilize information technology and sensors to provide adaptive and innovative services to efficiently utilize infrastructure and equipment, and to promote communication and citizen engagement (Chagnon-Lessard et al., 2021). Meanwhile, Zhang et al (2022) provide a short definition, referring to smart campus as deployment of advanced information and communication technology to enhance efficiency and effectiveness of campus activities, while stressing the importance of user-centric approach to this phenomenon. Furthermore, in their definition Imbar et al (2020) emphasize university's ability learn, resolve conflict among stakeholders, and utilizing their cleverness for intelligence of the whole system. Akbar et al (2023) approach the concept through earlier research by first defining quality of "smart" in this context as application of innovative, ground-breaking technology, and smart campus as application of this concept into campus environment, by providing supporting technology that improves effectiveness and efficiency of teaching process, and student learning experience. Another study by Malatji (2017) defines the word smart as "ability to show or demonstrate intelligence", and smart campus as an entity that intelligently interacts with its students and other stakeholders, just as a smart city interacts with its inhabitants and allows them to live easier and better life.

Ultimately, all these definitions seem to agree that it's not just application of advanced cutting-edge technology but applying it in human-centric ways that support campus stakeholders in their activities, that makes a campus smart. Furthermore, it appears that these valuable applications of technology should not result merely in isolated features of smartness here and there, but rather deeply integrate into the campuses everyday life and organizational processes, including but not limited to core activities of education and research, ideally forming a deep, seamless ecosystem of interconnected smart services. While building this ecosystem is typically an university-led effort (Muhamad et al., 2017), this ecosystem should also be able to utilize its stakeholder's collective intelligence (Imbar et al., 2020), and increase their engagement (Chagnon-Lessard et al., 2021). It can be argued that these insights further suggest the need for user-centric approach to the concept and its features, as advocated by (Zhang et al., 2022), making the building of a smart campus something that may evolve through the actions of all stakeholders, rather than merely through higher-led official initiatives.

While these definitions together form a comprehensive view of the smart campus concept, what they somewhat overlook is the definition of campus itself. Zhang et al (2022) defines campus as a "core place to provide educational activities", while Chagnon-Lessard et al (2022) considers it a "set of physical infrastructures serving higher education and research", while other studies discussed don't provide any kind of a clear definition. This suggests that previous research has largely focused on the topic through the lens of a traditional, physical campus where work and learning happen mostly locally. Even before the COVID-crisis this view may not have been very realistic, as remote learning was already gaining popularity as a more flexible alternative to in-place education (Lockee, 2021). Since then, the COVID-crisis forced universities all around the world to quickly adopt remote-learning as ubiquitous part of their operation (Lockee, 2021), and it remains a popular, convenient alternative to in-place learning even in current post-COVID crisis era. (Dos Santos, 2022). As defined in studies, a smart campus serves its stakeholders needs and organization's processes, and arguably a student or staff member who engages in university-related activities far away from physical campus is still an active stakeholder, whose needs should be considered when designing services for a smart campus. Thus, it can be argued that a definition of a smart campus should not include just the physical location, but also its remote aspects, such as enabling remote-learning and communication.

Based on these observations, for this study the concept of smart campus is defined as application of services that are perceived innovative and valuable by campus stakeholders, are supported by advanced technology, and integrate to all domains of the campus life in an interconnected manner, including secondary and core business processes and stakeholder's daily activities, both in physical and virtual, remote dimensions of the campus. Compared to some of the earlier research, this definition strongly argues that smartness of a campus is not solely a technology-first topic, but also a question of what is seen valuable and useful by stakeholders, capturing the user-centric perspective examined by Zhang et al (2022) in particular. It also stresses the importance of virtual campuses, which is crucial in the current era of remote learning where students and other stakeholders interact with each other without necessarily even being in the same countries (Dos Santos, 2022).

## 2.2 Application Domains

Following the concluding definition in the last chapter, a smart campus should include valuable smart features that integrate to all areas of campus life. This observation results in the need to somehow conceptualize and define these areas that are enhanced by smart features. The term "application domain" is used by Zhang et al (2022) in their research, while other articles refer to similar categories using different terms. It should be noted that from the perspective of smart campus features these application domains can be overlapping, as smart features may interact with multiple domains simultaneously (Chagnon-Lessard et al., 2021; Zhang et al., 2022).

In earlier comprehensive research, these application domains can be categorized as smart learning, living, environment and management (Zhang et al., 2022), smart people, living, mobility, environment, building, data and governance (Chagnon-Lessard et al., 2021), or smart learning, social, management, governance, health and green (Muhamad et al., 2017) as defined by Ng et al (2010). The additional literature reviews by Imbar et al (2020) and Akbar et al (2023) briefly explore various models, which appear to consist of similar domains. For the purposes of this study, the more comprehensive reviews by Chagnon-Lessard et al (2021), Zhang et al (2022) and Muhamad et al (2017) provide sufficient coverage of this topic. As Zhang et al (2022) found the least number of domains, it can be assumed that additional domains utilized other articles may be subdomains to this definition, and it can be expected that as the newest of the articles included, it may have the most complete picture of the topic. Thus, the definition by Zhang et al (2022) will be used as a basis on which categories present in other articles are compared to, with the goal of assessing the completeness of the domains and their subdomains defined in their model. More theoretical structures, such as frameworks, evaluation methods and benchmarks for smart campus development discussed in research by Chagnon-Lessard et al (2021) in particular, will be omitted here as the focus is on application areas for actual functional services that campus stakeholders can use. Figure (Figure 1) illustrates the theory of application domains adapted from Zhang et al (2022). In addition to the model presented by them, the figure includes additional subdomains marked with symbol *. These are smart social, which was included based on findings by Muhamad et al (2017), and smart data management, which was adapted based on findings by Chagnon-Lessard et al (2021).

It should be also noted that not all domain areas may appear equally important to all groups of campus stakeholders, even if they are important for its functioning as a whole – for example, the case study by Zhang et al (2022) noted that students and teachers valued smart learning, living and environment the most, while management was seen as less interesting. Similarly, Mustafa et al (2021) found smart learning to be the most important area to students, while Ahmed et al (2020) found topics related to learning, security, and environment to be of highest interest to students and alumni. These findings are something to keep in mind also in the context of this study, where the topic is a mobile application used mainly by students and staff in their daily lives. However, it's also important to note that what is seen important is affected by various environmental factors, such as students finding smart parking less useful in campuses where private car usage is less common (Přibyl et al, 2018), so the findings may not apply to all contexts. In the following chapters, the domains presented in figure (Figure 1) are discussed in more detail.

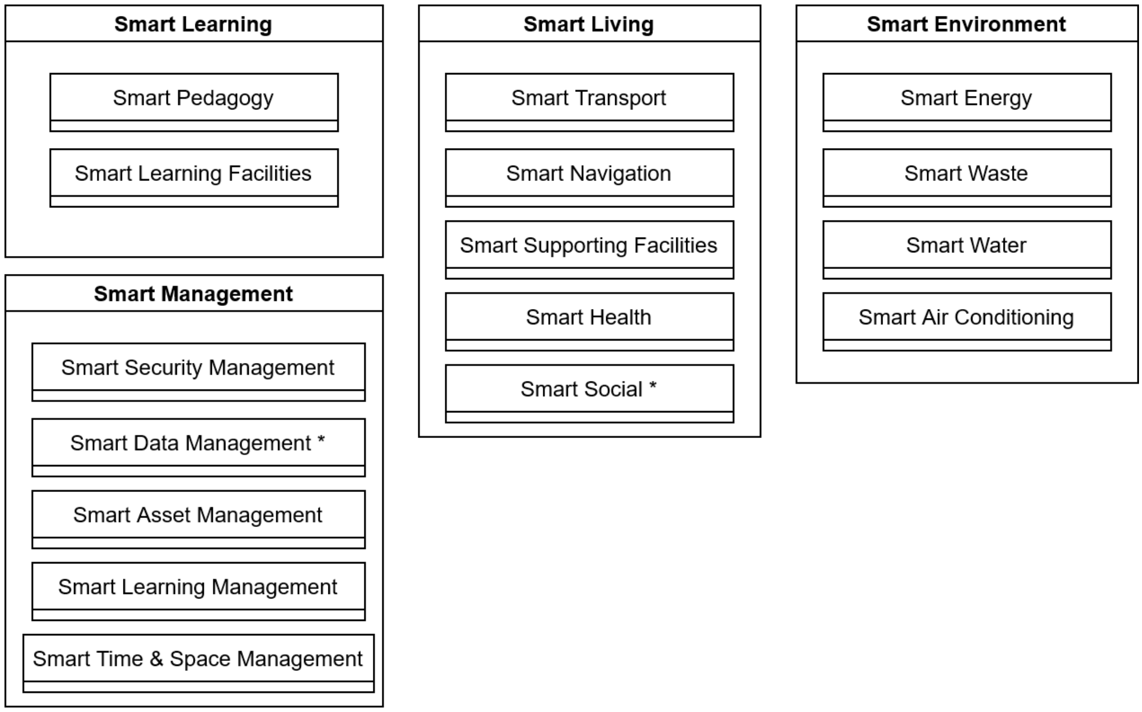


FIGURE 1 Application domains and their subdomains adapted from Zhang et al (2022)

### 2.2.1 Smart Learning

As education and facilitating learning are core activities of an university campus, it's not surprising that smart learning is appears to be the most researched domain of smart campus (Zhang et al., 2022). Through review of previous research articles, Zhang et al (2022) defined smart pedagogy, smart classroom, smart library, and smart laboratory as key subdomains where smart services are applied in the context of this domain. The smart pedagogy subdomain focuses on integration of technology in a way that has pedagogical value and supports various learning processes and styles. Smart classrooms on the other are about application of advanced technologies in support of classroom usage, facilitating interaction and management of the classroom environment, blending physical and digital spaces to provide interactive and immersive learning environments. Similarly to smart classrooms, the smart library subdomain focuses on enhancing traditional library facilities and services with smart features, improving knowledge sharing, ease of use and service efficiency. Smart laboratories apply technology to support specific needs of laboratory environment, improving activities such as automation and monitoring of data, equipment, resource and environment management, appointments, and information sharing. (Zhang et al., 2022)

In their research Muhamad et al (2017), utilizing iCampus model by Ng et al (2010), similarly define the research area of iLearning, with studies are grouped into subareas of smart learning management system, personalized learning, assessment, smart classroom, and library management system. Of these, the smart learning management system area is included under smart management domain by Zhang et al (2022). Otherwise, all these research areas defined by Muhamad et al (2017) can arguable be seen as matches or subdomains to the definitions by Zhang et al (2022) – personalized learning and assessment areas can be mapped into the smart pedagogy domain, delivering pedagogical value through personalization of learning processes, grading, analysis, and reporting of student performance. The smart classroom area maps directly to the domain of same name, while library management system, is a part of the smart library domain.

Unlike the two other sources, Changnon-Lessard et al (2021) don't define a research area of smart learning, but instead include themes related to it under the area of smart people. Under it, learning-related areas of knowledge transfer and collaboration, ubiquitous learning, gamification and virtual learning environments, student innovation, and smart classrooms and conference rooms are found to be present. According to Chagnon-Lessard et al (2021), knowledge transfer and collaboration is defined as something that can improve learning and skill development. Ubiquitous learning, defined as providing flexible learning opportunities anywhere and anytime, gamification and virtual learning environments are similarly applied to serve goals related to smart pedagogy domain. The category of student innovation is defined as participation of students in developing smart campus and doesn't obviously map to any of the smart learning subdomains defined by Zhang et al (2022). Nevertheless, based on examples provided by Chagnon-Lessard et al (2021), these participatory projects can also have pedagogical goals, such as fostering student's collaboration skills.

Overall, despite differences in terminology all three studies find themes related to smart learning central to the concept of smart campus, with subdomains of smart pedagogy and smart learning facilities, including classrooms, libraries, and laboratories, being central to this domain. Although Muhamad et al (2017) included smart learning management systems under this area, for the purposes of this research they will be included under smart management as done by Zhang et al (2022), referring mainly to the management and facilitating of learning activities, while smart pedagogy is concerned with actual implementation of those activities.

### 2.2.2 Smart Living

While learning is a core activity of a university campus, it's just one part of existence. At their largest, campuses can be seen as small cities, with typical city-issues such as transport, lack of parking spaces affecting them (Zhang et al., 2022), and even small smaller campuses are dependent on such services from surrounding environment. Thus, smart living can be seen as a central supporting domain for the functioning of campus, and appears to receive almost as much research attention as the smart learning domain (Zhang et al., 2022). The core subdomains in this domain found by Zhang et al (2022) are smart transport, smart canteen, smart health and smart navigation. Smart transport focuses on applying smart technologies in aid of transportation and traffic, including smartification of services such as parking systems, remote vehicle monitoring and public transport. Smart canteens utilize advanced technology to improve functions such as ordering, restocking, sales, and inventory management to improve dining experience, efficiency and reduce costs. The smart health subdomain, which became a particular topic of interest during the COVID-crisis, focuses on improving the health of campus users, through services such as remote healthcare, health monitoring systems, data analysis and warning systems. Related to smart transportation, smart navigation focuses on building geographical smart services to help campus users find locations both indoors and outdoors, and optimal paths to them. (Zhang et al., 2022)

Unlike in the smart learning domain, there's no area that quite matches this domain in research by Muhamad et al (2017). In their definition, smart parking is listed under the area of iManagement and can be seen as a part of smart transport in research by Zhang et al (2022). There is no reference to smart canteens or restaurants. However, conceptually the area of iHealth closely matches smart health domain, although Muhamad et al (2017) couldn't find smart campus related studies to the area at that time. Under iManagement area they list smart geographic information systems as their own subarea, matching the smart navigation domain by Zhang et al (2022). Importantly, Muhamad et al (2017) also define the area of iSocial as part of a smart campus, implying that social applications aren't solely for needs of education, but may also support other areas of life in the campus.

Similarly to Zhang et al (2022), Chagnon-Lessard et al (2021) define the area of smart living, which focuses on enhancing everyday aspects of studying, working, and living on the university campus. This area includes miscellaneous applications, such as virtual assistants that answer common questions, help with navigation and allow controlling of IoT devices. Many of these applications are also adaptable by utilizing data mining to provide a personalized experience and to recommend services based on user's behavior and real-time data. Several examples of smart navigation systems are also provided, with user's GPS-data used to show their location in the campus, and to recommend nearby services, or to help locating spaces. Interestingly, Chagnon-Lessard et al (2021) point out that they didn't find any food or canteen related smart campus research, nor is there any reference to research related to health in this area. Perhaps due to the model being adopted from smart city research, they do not include smart transport under this area, but instead define it as its own area of "smart mobility", which includes subareas of traffic monitoring, bus transportation systems, assisting navigation, electric vehicle charging and parking. This area of smart mobility matches the subdomain of smart transport. Additionally, under the area of "smart people"

Chagnon-Lessard et al (2021) explore research on campus stakeholders' perceptions of smartness, and monitoring stakeholder's opinions in campus-context. Under definitions by Zhang et al (2022), systems related to these areas could perhaps be best seen under the wide domain of smart living, as they essentially take user-centric and holistic approach to developing different features of smart campus in many areas. Additionally, under the smart people category Chagnon-Lessard et al (2021) briefly explore knowledge transfer and collaboration applications that aren't strictly confined to learning activities, but that could also be seen as a form of in-campus social media, with support for less formal communication.

Again, despite differences in terminology, all three research find many similarities in ways a smart campus can support stakeholders in their daily lives, with smart transport and navigation being perhaps the most central subdomains. Findings also suggest that supporting facilities, such as restaurants, can also be enhanced in valuable ways through utilization of smart services, and there's potential for health-related and social applications as well, suggesting the need to add smart social as its own subdomain that consists of applications that support socializing beyond study-related context.

### 2.2.3 Smart Environment

Just as campuses share difficulties of everyday living with cities, they are also affected by the same environmental challenges. With rising awareness of the importance of these issues, it can be argued that a smart campus initiative should also be a green one. Despite this importance, of the domains defined by Zhang et al (2022) this one received the least research attention, and can be divided into subdomains of smart energy, smart waste, smart water, and smart air conditioning. In all these subdomains advanced technology is utilized to reduce campuses carbon footprint, and to minimize excess and waste by utilizing resources more efficiently, while making the campus more livable. In practice this can include technologies such as IoT and AI to adjust heating, humidity and air conditioning based on facilities usage, and to detect leaks and other problems earlier, and to allow campus users to monitor these environmental parameters. In the subdomain of smart energy this can also include renewable energy generation through solar panels. (Zhang et al., 2022)

In research by Muhamad et al (2017), this domain is closely matched by the area of iGreen, which includes subareas of smart building, and water and waste management. In their definition, the smart building subarea consists of elements such as air conditioning, temperature and lightning control and reporting, so essentially, they've grouped the Zhang et al's (2022) subdomains of smart energy, water and air conditioning under this area, while smart water and waste groups together the two very similar subdomains by Zhang et al (2022).

Similarly to the other two research, Chagnon-Lessard et al (2021) define the research area of smart environment, with microgrids, waste management and recycling, and campus environmental monitoring as its central themes. Unlike two other research, they also define smart building as its own research area, which includes topics related to the smart environment domain, such as monitoring of energy usage and air quality with IoT sensors and utilizing big data and AI to predict and optimize future energy usage.

From the application domains discussed, this one appears to be perhaps most agreed on between different studies. All three studies emphasize the need to reduce carbon footprint, energy and water consumption and waste generation, which can be achieved through smarter, sensor and data-driven management of buildings and their energy grids, as well as through utilization of green energy. Thus, the original domain definition by Zhang et al (2022) appears complete enough, as the four subdomains of smart energy, waste, water, and air conditioning cover environment-related areas in two other research, while non-environment related aspects of smart buildings are covered in other domains.

### 2.2.4 Smart Management

With their size and wide variety of activities present in the other domains, there's an obvious need for effective management of the campus, guaranteeing normal-operation of the campus and its services, and full utilization of its assets (Zhang et al., 2022). The key subdomains found in this domain by Zhang et al (2022) are smart security, asset, time, and space, and learning management. Smart security management utilizes technologies such as IoT, cloud computing and big data to help detect, report, and respond to issues such as criminal acts, health hazards and disasters. Smart asset management refers to enhancing registration, maintenance, and supply of various campus assets through utilization of advanced technologies, allowing university management to ensure supply, reduce costs and improve efficiency. Similarly, smart time and space management can also improve efficiency by utilizing advanced technology to monitor room occupancy rates, and to plan scheduling and optimal allocation of rooms for learning activities, reducing under-utilization, and helping various campus departments synchronize their activities. Smart learning management focuses on building advanced learning management systems (LMS), which can help facilitate online learning and management of online-learning materials, communication between teachers and students, as well as monitoring in-class attendance. (Zhang et al., 2022)

In their research Muhamad et al (2017) define similar area of iManagement, consisting of subareas people identification, smart attendance, safe learning environment, smart parking, campus geographic information and bathroom management systems. Additionally, in iLearning area discussed earlier they define the smart learning management system subarea, which maps directly to the subdomain with same name defined by Zhang et al (2022). The people identification and safe learning environments areas are also clearly a part of smart security management subdomain, as both are concerned with security-oriented surveillance. Monitoring attendance and space usage for analysis and space allocation purposes in smart attendance area can be seen as a feature of smart learning management (Zhang et al., 2022). Smart bathroom systems could perhaps be mapped to the smart space management, though it appears to also consist of environmental aspects through reporting of water usage (Muhamad et al., 2017), making it more of subcategory of smart water usage in domain of smart environment. In addition to these aspects, Muhamad et al (2017) define the area of iGovernance, consisting of teaching management, financial and office management systems, which can be included under the management domain.

Similarly to Muhamad et al (2017), Chagnon-Lessard et al (2021) define the research area of smart governance, but under this definition it also includes themes central to smart management in two other research articles, with decision making and management systems as one of its subareas. Broadly, the smart governance area is defined as one consisting of themes related to planning, deployment, management, and evaluation of smart campuses. On a service level, it can include data-visualizing virtual campuses and data management and decision-making systems, which are often deeply interconnected with IoT-devices and other data-providing infrastructure of the campus (Chagnon-Lessard et al., 2021).

Additionally, Chagnon-Lessard et al (2021) define a top-level research area of smart data, referring to managing data in a way that makes it organized, protected from malicious intent, and accessible to authorized people. They argue this area to be the backbone of the entire smart campus paradigm, as analysis, exchange and safe management of data is essential for its functioning. This research area is further grouped into wireless sensor networks and infrastructures, middleware and IoT naming schemes, context-awareness, data storage, security and attack simulation and authentication. While this area has a clear overlap with technological domains with emphasis on networks and IoT utilization, it can be argued that it also has elements from the smart management domain. Data storage security and attack simulation is clearly an area related to smart security management, as is authentication, which deals with securing devices attached to smart campus networks and managing stakeholder's access to them.

In this domain all three studies again present similar themes, but there are major differences as well. Notably, Chagnon-Lessard et al (2021) make an important contribution by considering topics related to cybersecurity, while Zhang et al (2022) and Muhamad et al (2017) consider security mainly from a physical viewpoint. It can be argued that in a smart campus the two viewpoints are interconnected, as digital and physical worlds increasingly blend in through use of technologies like IoT. Further, by defining the related research area of smart data as a backbone of smart campuses functioning, Chagnon-Lessard et al (2021) do make a convincing argument for including smart data management as an additional subdomain of the smart management domain.

## 2.3 Technology Domains

As defined earlier, a smart campus consists of services that are perceived innovative and valuable by campus stakeholders and are supported by advanced technology. Thus, while the presence of advanced technology itself does not define the smartness of a service, it's still crucial to discuss advanced technology as a key enabler of building innovative and valuable smart campus services.

Similarly, to how different areas of campus activities were mapped into application domains by Zhang et al (2022), they mapped technologies into four technology domains of data computing and storage, IoT, intelligent, immersive, and mobile technologies, with IoT domain being most prevalent in previous research, followed by mobile, intelligent, data computing and storage and immersive technology domains. However, Muhamad et al (2017) didn't do such categorization, instead referring to specific technologies, which, listed in order of most prevalent to least prevalent in previous research, were radio-frequency identification (RFID), internet of things (IoT), cloud computing, 3D virtualization and augmented reality, sensory technology, mobile technology, and web services. Similarly, Chagnon-Lessard et al. (2021) referred to individual technologies, with IoT being most prevalent in previous research analyzed, followed by sensors, artificial intelligence, cloud computing, REST/RESTful APIs and GPS, and more specific technological implementations of Raspberry Pi and Matlab/Simulink.

Simply by observing these areas found in previous research and their prevalence, we can observe that IoT and sensors is a very researched technology domain in the context of smart campus, which is in line with earlier findings indicating a strong focus on physical dimensions of the campus. Cloud computing also appears very central, with AI also being very prevalent in research from this decade. All these findings suggest that the research on smart campuses is in line with wider trends in digitalization and computing, with most research focusing on technologies that are seen advanced and state of the art today. Nevertheless, we can also see examples of research on applying more traditional technologies, such as web services, web APIs and GPS (Chagnon-Lessard et al., 2021; Muhamad et al., 2017). With these findings, it's quite clear that a purely technological definition of what smart campus as application of "advanced technology" would be a fragile one, because what is seen as advanced, and what technologies are available is in a constantly changing state. Instead, systems and technologies seen as usual or traditional in present are likely to remain central in implementing features and services that are seen intelligent or smart. Deploying a basic web server may not be an exciting research topic, but on a practical level it may be central to making data generated by technologies like IoT or AI visible. Such overlapping and interaction of multiple technologies from separate domains indeed appears to be commonly required to actually deliver functioning smart services to campus stakeholders (Zhang et al., 2022).

Similarly to the chapter on application domains, we'll use the technology domains defined by Zhang et al (2022) as a basis on which we compare findings from the other two main studies by Muhamad et al (2017) and Chagnon-Lessard et al (2021) to form a more comprehensive understanding of how technology is applied in smart campus context. The figure (Figure 2) below illustrates the technology domains found by Zhang et al (2022), as well as additional subdomains of web services and API's, GPS and AIDC, which were added based on findings by Muhamad et al (2017) and Chagnon-Lessard et al (2021). The following chapters discuss these domains in detail.

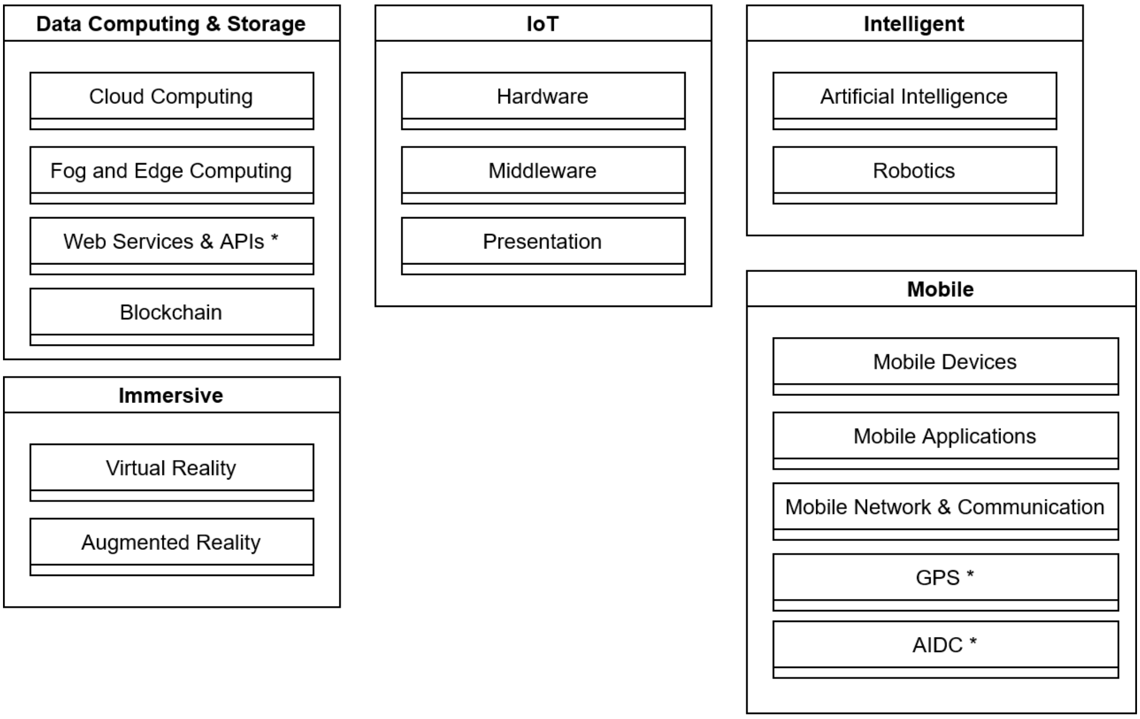


FIGURE 2 Technology domains and their subdomains adapted from Zhang et al (2022)

### 2.3.1 Data Computing and Storage

In the context of a smart campus the increasing use of sensor technology and other data-intensive technology can result in large amounts of data being generated, raising issues such as latency, storage, and energy consumption related costs, requiring application of advanced technology from data computing and storage domain (Zhang et al., 2022). The key subdomains in this domain defined by Zhang et al (2022) are cloud computing, fog, edge computing and blockchain. Cloud computing offers and alternative to traditional computation by allowing more flexible use and access of shared computational resources, increasing scalability, reducing costs, and enabling faster, ubiquitous data access that meets the needs of modern, flexible learning. Similarly, fog and edge computing increase scalability by distributing computing to large numbers of devices in local area network (LAN) level, enabling localized and real-time services that could be too slow when implemented in traditional centralized architecture. Blockchain follows concept of distribution by implementing real-time transactions through peer-to-peer decentralized database, although the research in this area appears to be scarce, with just one example of an campus electric vehicle energy-trading research provided. (Zhang et al., 2022)

Similarly to Zhang et al (2022), cloud computing is listed as one of the key enabling technologies of a smart campus by Muhamad et al (2017), describing it as a comprehensive solution allowing integration of many forms of information efficiently. Unlike Zhang et al (2022), they also list category of "web services" as one technology area, which can be seen as related to data computing and storage, as in practice these areas are deeply integrated to the web as their connecting communication technology. In the research by Chagnon-Lessard et al (2021) cloud computing is similarly described as a major technology in smart campus, with REST/Restful API's additionally seen as a significant related technology. Examples of cloud utilization can be found from many application areas - applying it to microgrids, energy use monitoring, learning and conference systems, and for handling data generated by IoT-devices. Examples of REST API utilization are not explicitly provided, but as a technology for building API's it can be seen central to all sorts of web-connected services.

Overall, all sources seem to agree that data computing and storage is a central part of smart campus infrastructure, providing a backbone for connecting various services and devices, and managing data gathered by them. Nevertheless, as noted by Muhamad et al (2017) and Chagnon-Lessard et al (2021), even with prevalence of cloud computing, traditional web services and API endpoints remain central to delivering smart services to end users. This makes sense, as essentially cloud computing is just a new way of hosting services in a more distributed and scalable fashion, rather than a complete replacement. Despite cloud's central nature, Zhang et al's (2022) case study found less interest in it by campus stakeholders compared to IoT and AI, but this might be explained by its nature as something that works in the background, rather than visible to end-users.

### 2.3.2 IoT

As defined by Zhang et al (2022), the idea of internet of things in campus environment is connecting many types of objects in the campus to the internet, allowing them to communicate together, with systems in the campus, and the campus stakeholders who can view data generated by them, and possibly control them over network. Implementing IoT-based services requires technology from multiple areas, which can be grouped into subdomains of hardware, middleware, and presentation. The hardware components include actual physical devices, such as cameras, scanners, sensors, routers, gateways, and RFID (radio frequency identification) tags. It's the role of middleware to facilitate communication of these diverse devices through interoperable interface protocol and allow managing them through device discovery and application abstraction related services. The presentation subdomain is concerned with presenting the data generated by the devices to the end-users, making it highly interconnected with mobile technology domain in particular, as mobile devices are the most common form of user interface these days. (Zhang et al., 2022)

IoT is also listed as a key enabling technology of a smart campus by Muhamad et al (2017), allowing building of smart systems that connect people, devices, and buildings in real time. They additionally discuss sensors as a separate, but related area, highlighting their role in supporting these smart systems by detecting things like human movement, temperature and humidity, water use, waste generation and use of locations. Of all technologies, IoT and sensors are also by far the most prevalent in research discussed by Chagnon-Lessard et al (2021). According to their research, they appear to be present in all application areas of smart campus and are discussed in detail in smart data area, with wireless sensor networks and infrastructure, middleware, IoT naming scheme as key IoT-related components. RFID tags are also found from various previous research and mentioned in this smart data category, highlighting their potential for tracking movement of objects within the campus. Similarly to the other two research, Chagnon-Lessard et al (2021) paint a picture of IoT-devices as one of the key technologies that are applicable to almost all areas of life on campus, and that enable connecting the physical and virtual dimensions.

With these observations, it appears that all three sources agree on IoT being among the most defining technologies of smart campuses, and also one that is of high interest to campus stakeholders as end users (Zhang et al., 2022). As noted earlier, a large portion of previous research appears to focus mainly on campus as a physical entity, and from that viewpoint particular focus on IoT makes sense, as it brings smart features to the physical dimension, and collects data from physical world for analysis and utilization in other services. It also appears evident that IoT is highly interconnected to the earlier technology domain of data computing and storage, IoT-devices and sensors may be a significant source of data generated.

### 2.3.3 Intelligent

According to Zhang et al (2022), intelligence can be seen as one of the key qualities of a smart campus and its services. While IoT-devices link the digital and physical world, the subdomains in the intelligent technology domain, which are defined as artificial intelligence and robotics, can help building smart campus systems that are more autonomous adaptive. Artificial intelligence allows solving problems involving uncertainties where traditional, cause and effect-based programming models do not work well, often utilizing the vast amounts generated data in support of decision making, quantitative evaluation, as well as for personalized learning and virtual tutoring assistants. Robotics on the other hand are defined as a kind of a physical presentation of AI, that can perform tasks autonomously. Technological development has made them more common especially in smart education sector where they are increasingly applied as learning objects, tools and aids which can be both subjects of study, and aiding assistants to students and teachers. (Zhang et al., 2022)

Interestingly, despite using terms like "intelligent systems", Muhamad et al (2017) make no reference to utilization of artificial intelligence or robotics in smart campus context. This may be due to the older age of the research, as AI and robotics have made major advances since the release of the article. Supporting this hypothesis, the newer research by Chagnon-Lessard et al (2021) indeed lists AI as the third most researched technology area of smart campus, just after IoT and sensors, with machine learning algorithms, fuzzy logic and artificial neural networks listed as the most common specific technology areas under it. They argue that generally through utilization of AI "smartness" can be added to many services without human intervention, and that machine learning and neural networks can be utilized to predict behavior, detect anomalies and act independently in response to them. In their research these technologies are particularly present in smart building application area, with AI-enabled solutions monitoring, analyzing, and responding to changes in building-related data, enabling savings in energy and water consumption. In smart living area, they argue that AI can also be utilized to understand and predict human behavior, to provide better responding services without human intervention. However, they make no reference to utilization of robotics.

Overall, based on these three research articles it appears that AI is growing area of interest to smart campus research, and to campus stakeholders as end users (Zhang et al., 2022), with a wide range of technological solutions and possible application areas in all domains of campus life. In comparison, robotics seems to be just an emerging technology, with high potential but limited application in this context for now. There also appears to be potential in connecting AI with technologies presented earlier, as AI could be utilized for advanced analysis of stored data generated by IoT sensors, and then issue commands to other IoT devices based on the analysis, as appears to be the case in proposed applications for smart buildings (Chagnon-Lessard et al., 2021).

### 2.3.4 Immersive

According to Zhang et al (2022), immersive technologies, consisting of virtual reality (VR) and augmented reality (AR) have become more common in smart campus context in recent years, and aim to provide a seamless connection between virtual and real-world environments. Virtual reality utilizes technologies such as VR headsets, glasses and haptic gloves and 3D displays to allow users immerse themselves in fictional or real-world 3D environments, which can facilitate learning and help with understanding abstracts concepts and simulations while creating more enjoyable and engaging learning. Virtual reality can also be utilized for modeling campus environments in digital fashion, which may provide information that is helpful for management and decision making. While virtual reality produces entire virtual environments, augmented reality is focused on only partially augmenting the real-world physical reality. This may be achieved even through use of basic devices like smartphones and tablets that allow filming the physical world and showing camera feed on screen, where additional information may be added. Similarly to VR, AR can help with providing more immersive and engaging learning experiences, and it has also been utilized to support navigation in campus. (Zhang et al., 2022)

Virtual and augmented reality are also listed as technologies of interest by Muhamad et al (2017), although they cite only one research article related to them, and don't refer to it as a key enabler of a smart campus, as they did for IoT and cloud computing. Similarly to Zhang et al (2022) they list navigation as one of the potential use cases for these technologies and argue that they can be valuable when integrated with sensors to provide real-time data of the surrounding environment. Compared to Zhang et al (2022) and Muhamad et al (2017), there is only limited focus into these topics of VR and AR in research covered by Chagnon-Lessard et al (2021) – word virtual reality is mentioned only once in context of gamification of learning environments with no concrete examples provided, while augmented reality is mentioned five times. Examples of augmented reality implementations were primarily mobile applications focused on assisting with navigation and providing information about user's surroundings, matching with use cases discussed by the two other sources.

Based on these observations it appears that VR and AR do have many interesting applications but are not necessarily central to the implementation of a smart campus, but rather a "nice to have". Notably, Zhang et al (2022) found in their case study that campus stakeholders didn't find VR and AR as interesting and useful as IoT and AI, even though these are inherently end-user facing technologies. Nevertheless, they are still interesting technologies with many possible application domains that may transform education in the future (Zhang et al, 2022), and it's possible that the lesser interest may also be explained by a degree of technological immaturity. This hypothesis appears to be supported by findings of a survey on AR and education by Zulfiqar et al (2023), which found technological limitations the most significant factor blocking wider adaption, and that despite these limitations, AR has already been adopted for learning purposes in many disciplines.

### 2.3.5 Mobile

As defined by Zhang et al (2022), mobile technology is the fusion of wireless devices and communication networks that connect them. With development of smartphones and mobile applications, mobile devices have evolved from one-dimensional communication devices into diverse, multi-tasking ones that provide numerous services often seen indispensable by their users and affect almost all application domains of smart campus. The key subdomains identified in this category are mobile devices, mobile applications and 5G networks. Mobile devices consist of smartphones with touchscreens, but also other devices with some form of monitor and input, such as tablets, wearables, and e-readers. While many of these devices are used to access traditional websites, highly interactive mobile applications have also become popular way to access different services in smart campuses, and may incorporate also other technology domains, such as intelligent and immersive technologies in them. Most of the time implementing services for mobile devices also requires communication with the world outside the device, and in that sector lies the 5G technology, referring to the fifth generation of cellular networks, which enable much higher data-transfer speeds and capacity compared to earlier 4G generation. This higher performance supports adoption of mobile technologies and IoT in particular, as it makes possible to connect more and more devices that transmit increasingly large amounts of data, without performance and efficiency issues that slower networks would have. (Zhang et al., 2022)

Similarly to IoT and cloud, mobile technologies, more specifically mobile devices and GPS and contactless communication technologies like Bluetooth, near field communication (NFC) and QR-codes are listed as key enablers of a smart campus by Muhamad et al (2017). According to them, the mobile devices can support smart campus by enabling learning from any place and time, helping navigation, and offering location-based services, while contactless technologies can augment and integrate to mobile devices to support access control and authorization to facilities. In contrast with two other research articles, Chagnon-Lessard et al (2021) have less focus on mobile technologies, with neither mobile devices, applications or 5G networks receiving that much attention. Nevertheless, they are all mentioned, with some examples provided. The potential to utilize mobile device's information gathering capability to build intelligent services is mentioned in smart living category, and their role is discussed in the topic of context-awareness as well. Several examples of smart campus mobile application research are also provided, with most of them involving utilization of GPS and other forms of positioning to help users navigate the campus, receive informational notifications, and based on their location, and send alerts to university security with location information provided. Some other use cases were also found, mainly focusing on utilizing mobile applications to gather data for analysis in support of services utilizing the data. The topic of 5G is mentioned only twice, with it playing mainly a supporting role for technologies such as IoT and cloud computing.

Overall, these studies suggest that mobile devices, their features such as GPS, cameras, and applications have a major role as end-user interface to many smart campus services. Next generation networks like 5G may also play a major role, mainly by facilitating usage of IoT and mobile devices, as they enable higher throughput and better network performance (Zhang et al, 2022). While the research by Zhang et al (2022) noted that mobile applications were not perceived as interesting to campus stakeholders as IoT and AI, they hypothesize that this is because mobile applications are already so common and satisfy many of campus stakeholder's needs, rather than due to actual lack of usefulness. For the purposes of this study, in addition to subdomains defined by Zhang et al (2022) GPS will be included as its own subdomain, and the domain of 5G will be extended to include other mobile network and communication technologies. Additionally, technologies such as RFID, NFC and QR-codes will be included under subdomain of automatic identification and data capture (AIDC), which appears to be a common term for such technologies.

# 3 SMART CAMPUS MOBILE APPLICATIONS

After discussing application and technology domains, it's time to explore how exactly they fit the picture in relation to smart campus mobile applications. In the context of this research, mobile applications refer to applications designed to run on mobile devices such as smartphones, tablets, and smart watches, including both native and web-based applications. While mobile technology was treated as just one technology among many in previous chapters, here mobile applications are at the center of the discussion, mapping their features to application domains, and supporting technologies to technology domains. Through this analysis, the research aims to explain what features smart campus mobile applications typically include, which application domain areas these features serve, and which supporting technologies are utilized to implement these features.

## 3.1 Application Domains and Technologies

Using search terms "smart campus AND mobile application", a total of 45 relevant articles discussing smart campus related mobile applications were found for this literature review. Some of the articles described the development of a single mobile application, while in others the mobile application was part of a study on a larger system. Descriptions of the features of the mobile applications were thematically analyzed, with 36 applications including features related to smart living, 11 to smart learning, 9 to smart management, and 5 smart environment application domains. A total of 13 articles included features belonging to more than one application domain, while the rest focused on a single domain. Additionally, one study by Cheng et al (2017) took a wider view by surveying official mobile application use in Taiwanese higher education campus context, and found features related to smart learning, smart living, and smart management application domains most prevalent. Figure (Figure 3) below illustrates the results of the thematic analysis, showing how features and technologies of the mobile applications discussed relate to application and technology domains defined earlier.

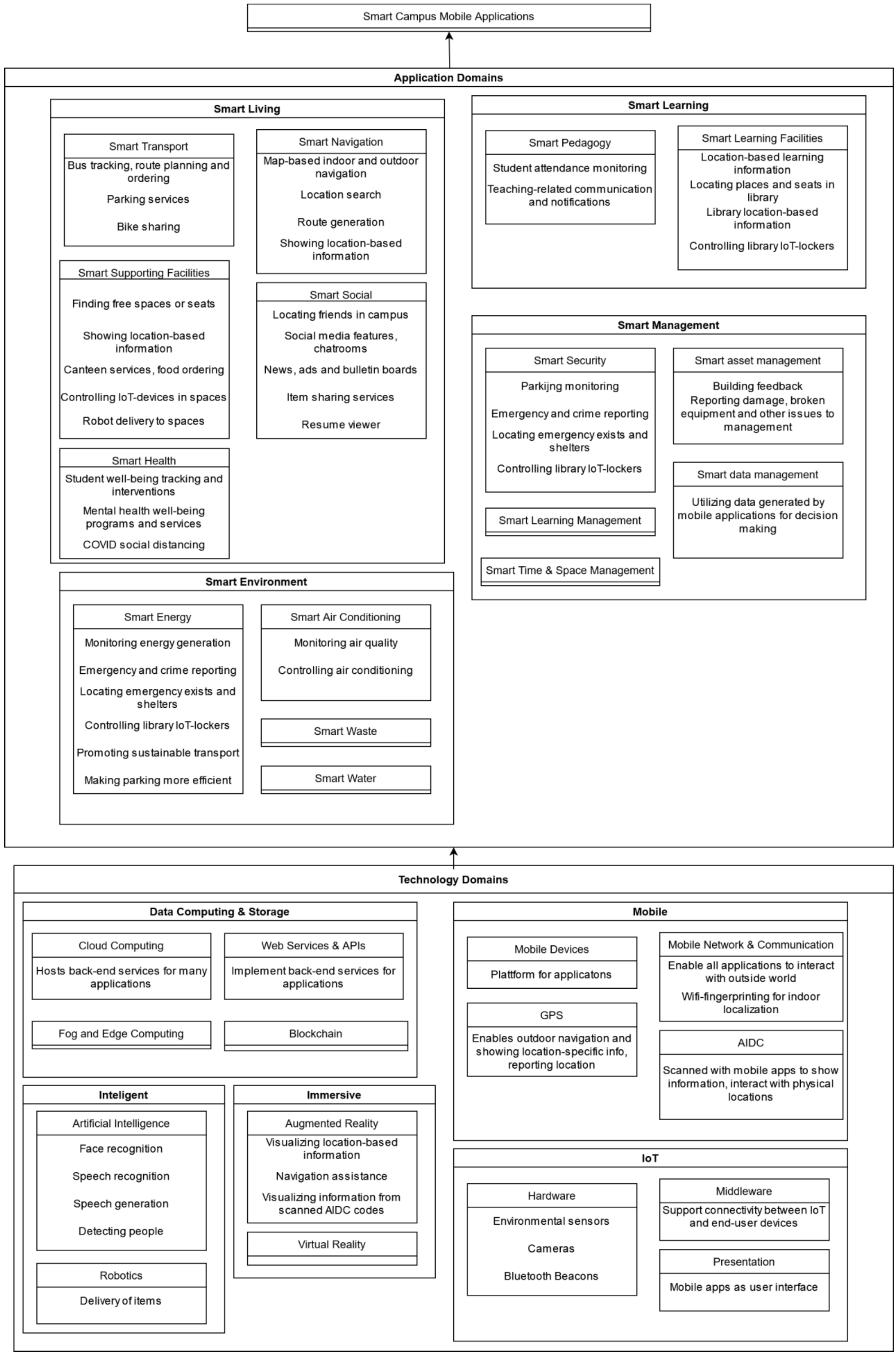


FIGURE 3 Relations of discussed smart campus mobile application ‘s features and application & technology domains.

### 3.1.1 Smart Living and Mobile Applications

As defined earlier, smart transport, smart navigation, smart supporting facilities, smart health, and smart social are the key subdomains of smart living application domain. With a total of 36 studies including features in some of these areas, it appears that domain is by far the most popular application domain for smart campus mobile applications.

Of the subdomains, smart transport appears to be the most targeted in mobile application development, with a total of eleven studies describing features related to it. In this subdomain, several studies focus on facilitating public bus transportation. Kamisan et al (2017) present a mobile application that allows users to track bus locations and predict their arrival. Another study by Sharif et al (2018) describes an app providing similar features, while also allowing route planning and monitoring number of people in bus stops. A mobile app discussed by Sobhana et al (2023) also allows tracking of buses, and notifications of their arrival. While features in these examples are mainly informational, a study by Fadhil et al (2020) describes an application that essentially allows students to crowdsource a bus, with management sending one when enough people have ordered it. In addition to bus transportation, various studies include mobile applications facilitating parking, allowing users to store their parking location to help find their car later (Aalsalem & Khan, 2017; Hammadi et al., 2012), and to find free parking spots based on real-time sensor data (Aalsalem & Khan, 2017; Bandara et al., 2016; Hossain et al., 2019; Vieira et al., 2019). Additionally, one study by Pakdeewanich et al (2020) describes implementation of a smart bike sharing, allowing borrowing and tracking of shared university bikes using a mobile application.

Compared to smart transport, smart navigation appears to be almost as popular subdomain for mobile application features, with a total of nine studies mentioning mobile applications with related features. Generally, these mobile applications can be grouped into non-AR and AR enabled ones. In studies regarding applications without AR-features, Hammadi et al (2012) describe a multi-feature android application that allows users to view map of the building, see information about their current location, search other locations, and interact with locations and management by completing place-specific surveys and giving feedback to management. Similarly, a study by Soldatos et al (2014) describes an application for locating free working spaces, their information and shortest path to them. Indoor locating is also central in study by Hadwan et al (2020), which provides a map of locations and indoor positioning to help finding locations. While these studies are map-based, Petrova and Tabunshchyk (2019) provide an interesting example of a voice-based mobile application with speech recognition and generation, aiding with navigation both indoors and outdoors. In the area of AR-enabled smart navigation applications, Chou and ChanLin (2012) describe an AR-enabled touring application that helps new students orientate with unfamiliar campus environments by providing information about locations. A study by

Torres-Sospedra et al (2015) describes a mobile application for indoor and outdoor positioning and wayfinding, with AR for showing information about location, and speech recognition capabilities integrated. Mannuru et al (2022) present a mobile application that, like many earlier examples, allows finding locations on map, but also allows scanning of landmarks to show details about them using AR, and utilizes AR features also to help with navigating to safety in case of emergency. In similar fashion, Pavlova et al (2022) utilize AR to draw fastest route to destination outside on top of smartphone's camera feed, while Sundarramurthi et al (2022) utilize AR in combination with QR codes to show details about locations, while also providing navigation features.

While smart transport and navigation related features assist users with reaching and finding locations, features in smart supporting facilities generally aim to improve their experience in those locations. In earlier research consisting of nine articles, Rinaldi et al (2016) present a mobile app that allows users to interact with sensors and other IoT-devices in campuses smart buildings and find free spaces. Y. Liu et al (2017) present an AR-enabled mobile application that shows information about current location in AR format. Van Merode et al (2016) discuss a mobile app, which shows dynamic information fetched from a content management system based on user's location in campus. In their multi-feature mobile application, Hossain et al (2019) describe smart canteen feature, which allows users to order food from canteen via mobile app, and Vatcharakomonphan et al (2019) describe even more comprehensive canteen mobile application, which in addition to food ordering allows users to predict queue length, rate restaurant, do e-payment, as well as allowing restaurant managers to track and manage orders. As an interesting break from pure smartphone-based applications, Kim et al (2019) present a combination of smartphone and smartwatch mobile applications, which allow students with disabilities interact with smart building's IoT elements, such as air conditioning. Lights, elevators, locks, as well as calls for assistance from staff. As an example of utilizing mobile device's various capabilities, Rusli and Halim (2019) present a mobile application which allows users to book free spaces and receive notification reminding them of the booking if they are not located in the space before booking begin time, utilizing Wi-Fi-fingerprinting for determining their current location. As rare example of combining robotics and smart campus, Nguyen et al (2021) discuss design of a delivery robot, that can be ordered to transport items like food, drinks and books to campus locations using a mobile application.

By their nature, campuses are also a place for social interaction, raising interest in the smart social subdomain. In nine research articles related to this domain, Dong et al (2016) presented demo of a smart campus mobile application, which featured social functions such as groups, forum, news, and trading of items. Similarly, Chaiwattanayon et al (2019) discussed a mobile application facilitating sharing and lending items in university campus through IoT-based kiosk. A multi-feature mobile application by Chuang et al (2022) included campus bulletin board for communication. As a more specialized feature, the mobile application discussed by Sundarramurthi et al (2022) included AR-based interactive resume viewer, showing student's resume when their ID card was scanned. Perhaps the most comprehensive social media type features were provided in mobile app presented by Yu et al (2011), facilitating both communication between friends and geographically locating them in campus. With even more emphasis on location, another mobile app discussed by Zhu (2016) allowed users to see and participate in discussions and chatrooms based on their location in campus, ask questions, invite friends to participate, and see location-based advertisements. While these examples facilitate human-to-human interaction, Chiu et al (2020) discuss implementation of an AR-based emotion aware virtual assistant that is integrated to mobile application, and can detect meaning and emotion from speech, and respond accordingly, helping users with daily tasks such as finding information about locations, restaurants, and general information. Gaglio et al (2019) similarly propose an assistive chatbot that can answer various campus-related questions and can be used through a mobile application. As a more specialized implementation, Sa-ngiampak et al (2019) discuss a mobile-app chatbot implementation for controlling IoT-lockers.

Perhaps surprisingly, only four research articles with features related to the smart health subdomain were found. Wang et al (2014) and Gjoreski et al (2015) described utilization of a mobile application to collect data from device's sensors to predict student's well-being and stress levels, potentially allowing intervention in case of issues. Booc et al (2016) discuss a mobile application that runs a psychosocial wellness program to improve student's mental health and provide easily accessible first aid to mental-health related issues. Another study by Tangtisanon (2021) describes implementation of a COVID-crisis era social distancing mobile application with facial recognition and localization of users to help maintaining safe distance, and track exposure in case of spread of the disease.

Overall, all main technology domains appear to be utilized in support of the features in smart living domain, with mobile technologies being most prevalent, followed by cloud and storage technologies, IoT sensors, immersive and intelligent technologies. In the mobile technology domain utilization of wireless networks, web servers and API's appears universal, as applications need to communicate with the outside world to build useful features, and often these back-end services are hosted on cloud platforms. Utilization of GPS for locating appears ubiquitous in context of transport and navigation, AIDC tags are commonly utilized to communicate information and track items, while IoT-sensors provide various ways of interacting with smart spaces and building environments, and immersive AR technology is utilized particularly in smart navigation domain to show routes, but also for showing additional location-based information. Compared to other technology domains utilization of intelligent domain appears limited, examples being delivery robots, emotion-aware virtual assistant, and speech recognition & generation.

### 3.1.2 Smart Learning and Mobile Applications

The smart learning domain includes subdomains of smart pedagogy and smart learning facilities. A total of eleven studies with learning-related features were found, with pedagogy-related tasks of attendance management and notifications about learning tasks making up eight studies, and smartification of learning facilities being the most central themes in remaining three.

In the area of attendance management and notifications Gopi et al (2016) developed an application with face recognition to track attendance and blocking of non-educational applications from student's smartphone while in class. Similarly, Jeong et al (2020) take an AI and IoT-camera based approach to attendance tracking, and Tangtisanon (2021) utilized facial recognition and Bluetooth beacons for facilitating safe attendance in the COVID era learning events. While face recognition appears central, also examples of other technologies used for attendance tracking can be found - Griffiths et al (2019) describe an application utilizing Bluetooth beacons for taking attendance, and for distributing quizzes and discussions in location-specific ways. Islam Mazumdar (2022) describe utilizing a mobile app in combination with NFC tags for similarly tracking attendance. In the notifications area, Chuang et al (2022) describe push notifications about beginning of a class as one of the main features of their application. Fadhil et al (2020) describe an application that allows students to receive push notifications about new grades, assignments, project tasks and resources on the courses they're participating in. In similar fashion, Yu et al (2011) describe an application that allows teachers to send notifications to students.

In the subdomain of smart learning facilities, Chou and ChanLin (2012) describe their AR-based mobile touring application as a form of educational technology, as it can provide location-based information for learning purposes. Oderuth et al (2019) describe a smart campus mobile app for library use, allowing students to locate free seats in library, filter library spaces based on number seats, receive notification of free seats, and store their bags securely in IoT lockers using RFID tags and sensors. Similarly, Romli et al (2020) describe an application for navigating in library, with AR-based features for showing details about library locations.

Like in smart living domain, elements from all main technology domains appear to be utilized in support of features of smart learning domain, with similar utilization of mobile networks, web, and cloud services for core functionality, IoT for smartification of physical facilities, and AR for informational features. In this domain, AI and AIDC technologies appear to be dominant in features related to attendance tracking.

### 3.1.3 Smart Management and Mobile Applications

The smart management domain includes subdomains of smart security, data, asset, learning, time, and space management. A total of nine studies were found with mobile application features related to this domain, with five of them being related to smart security, two to smart assets, and two to smart data management.

In the smart security subdomain, the smart parking application presented by Aalsalem and Khan (2017) allows management to detect wrongly parked cars and reach their owners through number plate recognition. K. Liu et al (2017) discusses a location-aware campus security application, which allows users to report emergencies to campus police department, with precise location given to them. Similarly, a multi-feature mobile app discussed by Chuang et al (2022) allows users to report emergencies to campus management, while Mohammed et al (2021) present a concept of a security Bluetooth button connected to a smartphone application, allowing users to alert campus authorities by pressing the button, with GPS, camera feed and person's information provided in real time to the authorities. Finally, an AR-enabled application discussed by Mannuru et al (2022) allows users to find emergency exists and shelters more easily.

In smart asset management subdomain Syafuan et al (2022) describe a GIS-based mobile app, which allows users to report different types of issues, such as damage, equipment not working or stray animals, to university management with location information and images included. Similarly, a multi-feature navigation mobile app by Hammadi et al (2012) allows users to give feedback to building's management for improvement.

Related to the smart data management subdomain, Booc et al (2016) describe features that allow administrators to manage peers, view statistics and effectively monitor the use of a psychosocial wellness application, allowing better data-based understanding of mental health in the campus. Similarly, in their research Torres-Sospedra et al (2015) note that their navigation application can also serve as an analysis tool for managers and their decision-making processes through the data platform it's connected to, allowing optimizing use of resource such as classrooms. Following this example, should be noted that also a wide range of other database-utilizing applications described in various domains may be useful from the point of view of smart data management, even if they do not explicitly include management-oriented features.

Again, technologies from all domains are mentioned in the articles, with similar emphasis on mobile technologies. Utilization of GPS appears popular for location-based reporting, while data computing and storage technologies are central for facilitating smart data management.

### 3.1.4 Smart Environment and Mobile Applications

The smart environment domain includes subdomains of smart energy, waste, water, and air conditioning. Six articles were found with descriptions of mobile application features with some connection to these areas. Three of the articles were related to monitoring or controlling environmental sensors, IoT-devices and their data in smart buildings, while three others were traffic management related applications with reducing environmental impact listed as one goal.

In the monitoring and controlling area, a mobile application presented by Rinaldi et al (2016) allows its users to monitor building air quality, temperature, acoustics of rooms and amount of energy generated by buildings and includes bi-directional features with building adapting based on user's usage and preferences. Another mobile application by Hossain et al (2019) similarly allows monitoring of building's environmental data. A combination of smartphone and smartwatch applications described by Kim et al (2019) allows students with disabilities to control air conditioning using speech or gestures.

In sustainable traffic area, the navigation application by Torres-Sospedra et al (2015), parking application by Vieira et al (2019) and bike sharing application by Pakdeewanich et al (2020) all list promoting sustainability as significant goals of the applications. It could be also argued that the various smart public transport related mobile applications presented earlier do have an environmental aspect into them, perhaps more so than the smart private car parking app by Vieira et al (2019), but for the purposes of this categorization only ones with mention of sustainability motivations are included.

Similarly to earlier applications domains, mentions of technologies from all technology domains can be found from research articles linked to the smart environment domain. Compared to other application domains, IoT technology appears particularly central here through use of environmental sensors.

## 3.2 The Potential Future of Smart Campus AI Assistants

The presented literature review of smart campus mobile applications shows that artificial intelligence already has many use cases in the context, ranging from face recognition (Gopi et al., 2016; Tangtisanon, 2021) to speech recognition (Chiu et al., 2020; Kim et al., 2019; Petrova & Tabunshchyk, 2019), recognizing number of people (Sharif et al., 2018; Vatcharakomonphan et al., 2019) and even to producing speech (Chiu et al., 2020; Kim et al., 2019). Nevertheless, due to the fast development of this technological domain, it can be argued that these articles may not fully present the extent of potential use cases in the future, implying a need for further examination of this domain. Since the end of year 2022, emergent large language models and chatbots based on them, such as ChatGPT, have become widely used by and transformed numerous fields, including education (Wu et al., 2023). In the educational context, it appears that such models are particularly useful for various study-related activities, such as text generation, summarizing, translation and code generation, and also for general conversations (Laato et al., 2023), and are likely to become a major transformative force on modern education (Gill et al., 2024). In addition to the potential there are also risks, such as producing misleading information, and outputs that look convincing but are factually incorrect, stressing the need for the ability to critically evaluate the answers (Shoufan, 2023). In any case, LLM-based tools such as ChatGPT are already widely used by university students, and are generally appreciated for their ability to provide detailed, well-structured responses in natural language (Shoufan, 2023).

While possible applications of large language models into smart campus context are likely to be numerous, it can be argued that their conversational nature (Laato et al, 2023) and ability to understand a wide variety of inputs and produce coherent responses (Shoufan, 2023), makes them a prime candidate for utilization as a core part of assistive mobile applications. In previous research it has been noted that inability of understanding human expression and emotion sufficiently can be a major flaw in implementing educational chatbots, ultimately resulting in users becoming disengaged with their use (Chen et al., 2023). Indeed, in the smart campus context there appears to be many successful implementations of speech recognition and generation, but applications with more complex conversational capabilities seem to be scarce, likely due to limitations of earlier technology. Based on this, it can be hypothesized that thanks to their improved conversational capabilities, large language models may bring a new era of more intelligent assisting mobile applications to smart campuses. Similarly to assistive chatbot mobile applications proposed by Chiu et al (2020) and Gaglio et al (2019), such assistants could provide chat-based conversational interfaces for helping with many areas of life in the campus, rather than being single-purpose applications. Unlike existing general purpose smart assistants such as ChatGPT, they could be tailored for the needs of the campus stakeholders, potentially integrating to existing systems in real-time, similarly to many traditional mobile applications discussed earlier. Nevertheless, due to the novelty of the technology many questions remain regarding the practical implementation of such assistants, such as the tendency to provide unreliable information, and whether users really prefer conversational interface over traditional user interfaces. Perhaps the most likely scenario is one where conversational interfaces augment traditional user interfaces of existing mobile applications, allowing users to find features and achieve some tasks faster through conversation, while others are best done through traditional user interfaces. With these observations, it seems evident that there's a need for further research on user attitudes towards integration of novel AI-based features, including conversational assistants, into smart campus mobile applications.

## 3.3 Findings and Implications

This literature review began by exploring the definition of smart campus and its dimensions, utilizing previous comprehensive research by Muhamad et al (2017), Chagnon-Lessard et al (2021) and Zhang et al (2022) to form a model of smart campus application and technological domains. After that, a total of 45 individual case studies were analyzed from the viewpoint of this model, to see how smart campus mobile applications are positioned in relation to model's domains.

Based on the review, it appears that the utilized model of smart campus application and technological domains can be useful for analyzing the features and positioning of smart campus mobile applications in relation to the wider smart campus context, and that features of existing applications fit the model well. On the application domain side analysis found features belonging to all main domains, and to most of their subdomains, only exceptions being smart waste, smart water, smart learning and smart time and space management. It can be assumed that the lack of features related to these subdomains may be caused by them being more of a management concern of a limited number of staff responsible for these areas, rather than something directly affecting a larger number of stakeholders. In technological domain side similarly, all domains were utilized by at least some mobile application features, including all subdomains except for blockchain and virtual reality. Lack of mobile applications related to these two subdomains appears surprising considering their popularity in recent years and could possibly be caused by the review being limited only to studies with the concept of smart campus being directly mentioned in them.

By observing the results of the analysis, it's evident that features related to the smart living domain very much dominate the landscape of smart campus mobile applications, with features belonging to this domain being over three times as numerous as those in next most popular domain of smart learning. This finding is roughly in line with results of a similar but more limited study of campus mobile apps in Taiwanese context, where smart living-related topics also dominated (Cheng et al., 2017). Despite learning being one of the core activities of campus, it seems that many mobile applications created by smart campus initiatives are more concerned by facilitating supporting activities, such as transportation, navigation in the campus and providing smart services integrated to university's physical spaces. This stands in contrast to findings of more general studies on smart campus, which found the learning domain to be roughly equally popular research area to smart living related topics (Muhamad et al., 2017; Zhang et al., 2022), and the domain students appear to show most interest towards (Ahmed et al., 2020; Mustafa et al., 2021; Zhang et al., 2022).

It can be hypothesized that this dominance of smart living domain in mobile applications is due to many learning related activities being performed mainly in the context of more traditional browser-based learning management systems. It's also possible that there is simply a better availability of existing third-party mobile applications for supporting learning-related activities, while smart living related features are more likely to require custom in-house solutions, which studied smart campus applications often appear to be. Similarly, the high availability of third-party social media applications could perhaps explain the relative rarity of features related to the smart social subdomain. In the smart learning domain, it's also noticeable that most application features focus on facilitating conditions, such as tracking attendance, allowing teachers to communicate with students, and finding places to study, rather than being core parts of the learning experience itself. Again, it may be that those core learning activities are already covered by other applications, but it does still leave open the question of whether applications built to serve smart campus initiatives could also play a larger role to aid students in their learning journey. With many application features being centered around physical campus, it's also worth considering whether applications could do more to support remote learning that remains common in post-COVID era.

Aside from smart living and learning, the findings from smart management and environment domains illustrate how features related to themes such as security, building environment management and issue reporting can serve both average campus users and the management, and provide useful data for responding and decision-making. Indeed, it can be argued that Chagnon-Lessard et al's (2021) claim of smart data being the backbone of a smart campus has its merits, as ultimately availability of right data appears central for implementation of advanced features from all domains. However, due to heterogeneity of different data sources integrating data together to build such features isn't always a straightforward task (Roda-Sanchez et al., 2023), and would benefit from wider adoption of open standards for devices and systems Chagnon-Lessard et al (2021). While there are privacy concerns to keep in mind, ideally smart data initiatives could also include open data, which would enable crowdsourcing of smart campus applications (Chagnon-Lessard et al., 2021), potentially allowing smart campus ecosystem to grow organically as opposed to purely management-led effort.

In the technology domain side, it appears that at least some technologies from each domain are present in articles mentioning features related to all application domains. Generally, mentions on usage of technologies from mobile technology and cloud & storage domain appears to be most common with IoT domain coming third, and with immersive technology domain coming further behind, and artificial intelligence mentioned in comparatively few articles. These results differ from the study by Zhang et al (2022), where number of articles with IoT domain is larger than those form mobile technology domain, and number of articles featuring intelligent technologies is much more prevalent than in these results, while immersive domain appears less prevalent. Further, in their case study Zhang et al (2022) found that teachers and students appeared to be highly interested in practical applications of IoT and AI, while AR appeared less attractive. This suggests that AI and robotics related services may be underutilized by smart campus mobile applications, while AR is highly utilized, probably because mobile devices with their integrated provide a natural platform for many such solutions. Generally, in mobile technology domain it appears that mobile networks as well as GPS are utilized by very many application features, which is to be expected as most applications need to communicate with the outside world, and many of them have location-based features. AIDC technologies like NFC and QR-codes also appear popular means of tracking and transferring information locally. Integration with IoT sensors appears to be a very popular way of connecting the applications with the physical campus, ranging from supplying environmental data to controlling devices like smart lockers and air conditioning. In the data computing & storage domain explicit mentions of utilization of cloud computing as backend service are very common, but many applications also seem to feature locally hosted backend services. As nearly all applications communicate with the outside world, traditional web services and API's are an ubiquitous part of their supporting technologies, although earlier categorization by Zhang et al (2022) didn't include them as a subdomain. Usage of augmented reality from the immersive technology domain appears to be mostly centered around navigational and informational features, with AR providing guidance or information on top of device camera feed. In the intelligent technology domain utilization of AI features like face, people and registration plate detection appear central, with just one mention of robotics in the context of a delivery robot. It is notable that despite discussing technologies and solutions with obvious privacy implications, many of the articles include no mention of the privacy aspects, suggesting a need for further research covering that perspective.

Overall, it can be concluded that mobile applications built for smart campuses can benefit campus stakeholders in all domains of campus life and utilize a wide variety of technologies from different technology domains in support of their features. Nevertheless, it appears that many previously researched mobile applications remain one-dimensional rather than including features from multiple different domains, and that their current use is often limited to physical campus related assistive functions in smart living domain, such as facilitating transportation, navigation, and general information sharing. This suggests a need to consider whether they could be utilized more in support of university's core activities of education, learning and research, and whether they adequately serve the needs of remote students and workers. The fast development of artificial intelligence in the past few years is also likely to bring opportunities for adopting this currently underutilized technology domain in support of new features. From an end-user perspective, large language model's conversational capability may prove to be particularly useful in form of smart assistants and chatbots that are integrated into campus infrastructure, while their capability to analyze transform text may prove to be useful for many other applications as well. While the potential of these promising technologies is exciting, it is still traditional web servers, databases, API's, and cloud computing that ultimately form the infrastructure required for integration of mobile apps different services, and thus remain central to any smart campus initiatives. Also, as noted by Zhang et al (2022) smart campuses services ultimately exist primarily to benefit its stakeholders, creating the need for a user-centric approach to their development, as opposed to technology-first attitude. The rest of this article follows such an approach, utilizing a case study as the means of observing the actual use and needs of the users of a smart campus mobile application.

# 4 EMPIRICAL STUDY

The University of Jyväskylä developed the MyJYU smart campus mobile application for Android and iOS platforms as part of its digital development program's smart campus initiative. The development work performed by university's digital services began in year 2018 in close collaboration with university's IT faculty, and the application entered service in spring 2019, targeting primarily students, with about 5000 users by the end of year (Lumor et al., 2020). Since then, development of the application has continued, with many major features added, including ones targeting staff and visitors in addition to student users. In 2022 the application was also completely rewritten using Flutter framework to allow easier and more flexible development compared to the original low-code platform-based implementation. By the end of the 2023, the total userbase had risen to about 5700 users.

Generally, the features of MyJYU application can be divided into ones available to all user groups, and those targeting staff or students. Features available to all users include listing of university's events, news, jobs, campus restaurant menus, campus map, event calendar, QR-code reader, service catalogue, university sports and general search for university related information. Additionally, students can access the list of the courses, modules, and degrees they've completed and corresponding grades, and see a calendar of their lectures, as well as show sports ticker required when attending university's sports classes. Both students and staff can order and show a digital library card, search for available spaces to reserve, and reserve them through the application, as well as view processes related to them through an external process automation platform that has its user interface embedded in the application. Finally, staff users can access a work time tracking application through the user interface, allowing them to easily check in and out of work regardless of their location.

Notably, most of the features are based on the university's existing web-based API's system infrastructure for services that are also accessible through the university's website. In addition to this technological infrastructure, external cloud-based services are utilized for several features, while sensors such as GPS and device camera are used for location-based features, such as showing user location on map, and displaying room-specific calendars by scanning printed QR code. Thus, MyJYU can essentially be defined as a multi-feature mobile application (Lumor et al., 2020) that integrates with both digital and physical dimensions of the campus, with a goal of making most important services in user's daily lives more accessible and easier to use. Indeed, based on findings by Lumor et al (2020) it appears that completeness and uniqueness of application's feature set are major motivating factors for its adoption. The application also allows a degree customization, such as displaying menus of favorite restaurants on the front page, which also appears to positively influence its adoption, although it may simultaneously reduce later exploration of application's other features (Lumor et al., 2020).

As noted by Lumor et al (2020), the application began as primarily an informational application targeting students, with only limited functionality for staff, and few that would allow users to actively interact with services, rather than merely consuming information provided them. Since then, new integrated features such as space reservation, digital library card, work time tracking, and process automation platform have gradually turned the application from purely informational into a more active and interactive one and have made it more attractive to staff users. Through ongoing development for many new interactive features, this trend is expected to continue, with the application playing ever larger role in making smart campuses services accessible to its users. However, it's important that this vision for future development is based on actual, verified needs of the users. Major trends, such as increased remote work and learning and utilization of AI have transformed the way campus stakeholders conduct their daily activities, which means earlier user research may not reflect the wishes and needs of users in today's environment. For this reason, this qualitative empirical research aims to bring an up-to-date view on user's current usage and future wishes, aiding planning of future development, while also contributing to existing theory discussed in literature review. The model of application domains defined earlier will be used as a background and aid for qualitative research analysis, helping reflect which areas of campus live application users prefer the MyJYU application's current and future features to focus on. Ideas for potential to utilize artificial intelligence will be explored, but otherwise this part of the study will not focus on technologies to keep the size of the study manageable within limited time and resources.

## 4.1 Qualitative Research and Thematic Analysis

Research methods are typically grouped into quantitative and qualitative ones. Sometimes these two research traditions are even described as exact opposites, or qualitative research as a critique of quantitative research, but in practice mixing research methodologies from the two traditions within a single study is also possible (Tuomi & Sarajärvi, 2018). According to Myers (1997), quantitative methods were originally developed for the needs of natural sciences, while qualitative methods were developed in social sciences for studying social and cultural phenomena. This focus on the human aspects makes qualitative research also attractive from the viewpoint of information systems science research, as there the area of interest is often human organizations, and their information system use (Myers, 1997).

In the context of this study the focus is inherently human-centered. The university is an organization formed by human stakeholders, who interact with the campus, its smart services and MyJYU mobile application. The application domains defined in literature review describe areas of human function in the campus, and the subject of study are the current usage and ideas towards future development of the application, and how they relate to the application domains.

Thus, it can be argued that from a theoretical perspective qualitative research is well suited for this study, as it allows rich description and analysis of user's feedback, ideas and attitude, providing an user-centric perspective, which would generally be hard to present in quantified form without losing valuable details (Kaplan & Maxwell, 2005). From a practical perspective rich, detailed descriptions of user's ideas and their common themes are likely to provide more material for feature development than mere numerical quantities of different types of ideas or requests. Indeed, Kaplan and Maxwell (2005) argue that qualitative methods can be particularly valuable when the goal is improving existing system, rather than merely evaluating satisfaction in an existing one.

Qualitative research is not a singular entity, but rather a high-level concept, which contains many different methodologies for conducting empirical research through collection and analysis of qualitative data. The decision on methodology for research is important, as not all methodologies may be equally suitable for answering a particular research question (Tuomi & Sarajärvi, 2018), and the choice of methodology influences the way collection of data is conducted (Myers, 1997) and analyzed (Tuomi & Sarajärvi, 2018). The possibilities for conducting qualitative research are indeed numerous, and include methodologies such as action research, case study research, ethnography and grounded theory, content analysis and thematic analysis (Braun & Clarke, 2006; Myers, 1997; Tuomi & Sarajärvi, 2018). Elements of these different methodologies can sometimes be combined or overlapping, and hard to differentiate exactly – for example thematic analysis and content analysis are closely related, with latter more often used to quantify qualitative data, while grounded theory is sometimes used in a way that resembles them (Braun & Clarke, 2006). From the viewpoint of this study, it can be argued that case study and thematic analysis are methodologies of particular interest.

According to Myers (1997) case study is commonly used in information systems science to study information systems in their organizational context. In case study methodology, the research is designed around a single, contextual case that is a limited example of a wider phenomenon, which is then explored in great detail to gain understanding that phenomenon of interest (Kallinen & Kinnunen, 2021). It should be noted that as the focus of a case study is a single case, its goal is not to generate universally applicable results, such as models or theory to be applied into all cases, but rather provide detailed description that can grow understanding on the wider phenomenon (Kallinen & Kinnunen, 2021). In this empirical study, the goal is to grow understanding of how smart campus mobile applications are used in support of life on campus, and what kinds of features users wish from them by closely examining a single case, the end-user feedback on MyJYU application. Thus, this study can be defined as a case study.

On a practical level, a study being case a study doesn't dictate what analytical methodologies can be used to actually observe the defined case, and in that sense the concept of a case study is more of a high level strategy of research than a full analytical framework (Kallinen & Kinnunen, 2021). In the literature review of this research, features of smart campus mobile applications were discussed through the theory of application domains. This theory can be seen useful also in the context of this empirical case study, as the feedback on MyJYU can be analyzed through the theory of application domains, to gain understanding on how the application is currently positioned in relation to different domains of life in the campus, and where its users would want to see it headed. One way to do this is by analyzing what kind of features users currently use the most, and what sort of features they want prioritized for future development. These observations could be then used to form common themes of features, which can be then mapped into application domains defined earlier. This kind of a process can be performed through the methodology of thematic analysis, where qualitative data is first codified by summarizing meaning or features in it, and then analyzed and grouped into common themes to provide new insights and understanding (Braun & Clarke, 2006). Similarly to qualitative analysis in general (Tuomi & Sarajärvi, 2018), thematic analysis can be either inductive, where themes arise through codification process, deductive, where codification and forming themes is done from the perspective of existing theory (Braun & Clarke, 2006). Further, deductive qualitative analysis can be seen as either theory-based, where theory strongly controls the data collection and analysis or theory-led, where data-collection can be rather freeform, but existing theory is still used in aid of the analysis (Tuomi & Sarajärvi, 2018).

Following these observations, this empirical case study will include a deductive thematic analysis that is theory-led, where user feedback and ideas are analyzed primarily from the viewpoint of the application domain theory, but the collection of data itself isn't strictly based on the theory. In addition, the study will explore the ideas towards AI usage as part of the application, mainly from the viewpoint of how artificial intelligence could serve the features of different application domains. While this analysis will be mostly deductive, it should be noted that the deductive and inductive approaches both have their advantages and disadvantages. A deductive approach can provide a more detailed description of a particular aspect of data, while missing some other aspects, while an inductive approach may provide a richer description overall, but is less likely to directly answer a predetermined specific research question (Braun & Clarke, 2006), and may be more problematic to implement in practice, as researcher's existing understanding of research area is more likely to affect the analysis of data, even when it's not a conscious decision (Tuomi & Sarajärvi, 2018). For the purposes of this study the deductive approach appears the most sensible, due to the model of application domains, which was found to be useful for analyzing features of smart campus mobile applications in the literature review. However, also themes outside of application domains will be included in the analysis, if they appear significant for answering the research question.

## 4.2 Gathering of Data

With case study and thematic analysis being chosen as central research methodology, there is still the question of data and its collection. Case studies typically include data from multiple sources to build a detailed view of the case being studied (Kallinen & Kinnunen, 2021). Interviews are the most commonly used way of collecting qualitative data, with structured interviews that follow a predefined script, unstructured interviews with more open flow, and group interviews with multiple people being interviewed all being options for qualitative research (Myers & Newman, 2007). In addition to interviews, surveys are also utilized to collect research data. Unlike in an interview which is based on real-time communication between interviewee and the person being interviewed, in survey the respondent fills a predefined form, with the researcher playing a more passive role (Tuomi & Sarajärvi, 2018). Surveys are more commonly used in quantitative research, but they can be also useful tools for qualitative research (Braun et al., 2021; Tuomi & Sarajärvi, 2018). Compared to interviews, surveys are fairly fixed, as typically the researcher is not present when the survey is being completed, which prevents the respondent from asking clarifying questions, and the researcher from presenting further questions based on responses, as could be done in an unstructured or semi-structured interview (Tuomi & Sarajärvi, 2018). However, qualitative surveys tend to be cheaper and less time-consuming to perform (Tuomi & Sarajärvi, 2018), and may have other advantages that allow capturing larger number of responses, while maintaining high quality of data (Braun et al., 2021).

To collect a representative set of data on usage, ideas, and attitudes towards MyJYU's features, it's necessary to get data presenting opinions of both students and staff users. As the scope and resources available for the case study are limited, it's preferable to utilize both existing material, and material obtained through new research. In early 2023 a staff workshop was performed to collect feedback and development ideas on MyJYU's features. The questions in this workshop were mostly open-ended, which helped to provide a wide variety of rich responses from a fairly large number of respondents, and thus they can be seen as useful material for qualitative analysis. A survey consisting of similar questions was conducted on students in 2021 during the COVID crisis induced remote learning period, but since then there has been no similar large-scale survey. For this reason, it's necessary to conduct new user research on students to gain up-to-date data in current times, where on-campus learning is again happening, and new trends such as AI-based chatbots are transforming education. While qualitative interviewing could be an option, as was performed on the previous MyJYU-related study by Lumor et al (2020), it's likely that a web-based survey will be able to reach a higher number of respondents, consisting both in-campus and remote learners from many faculties, within the available resources and time.

### 4.2.1 Staff Workshop

As described earlier, existing data from a staff web-based workshop gathering ideas and feedback on MyJYU's usage and features is utilized to enable analysis from viewpoint of the staff users. On a general level, workshop can be seen as an arrangement, where groups of people learn, acquire new knowledge, and solve problems or innovate in a context of some domain-specific issue (Ørngreen & Levinsen, 2017). Aside from this practical viewpoint, workshop can be also used as a distinct research methodology, where its goal is to produce reliable and valid data in a forward-looking manner, such as when planning for organizational change or development (Ørngreen & Levinsen, 2017). The staff workshop discussed was conducted by university's digital services in March 2023, and utilized a web-based workspace tool where attendees could write down their ideas and feedback on a web page, as well as vote for the most popular features and ideas. Already before the workshop, attendees were asked to install the MyJYU application if they hadn't done it already and use it for at least a week, writing down feedback and observations on application's current state to the workspace. On the actual date of the workshop attendees then met in an organized Zoom meeting lasting three hours, where they were divided into small groups, and given the task of creating ideas for development of new features that would benefit staff users generally, and different subgroups such as researchers and teachers. This creation of ideas was rather free form – it was emphasized that the responses should focus "what and why", rather than concrete implementation details. Additionally, following three leading questions (translated from Finnish) were presented to help the idea creation process:

- You are on the campus / work trip / remote work with your phone in your hand. What would you do with it to make your day easier?

- Think about challenges in your daily life for a moment. In which situations do you notice that something is annoying / difficult / frustrating to do in way X?

- If the same person has multiple roles (student-staff; teacher-researcher etc), how should these roles be visible in MyJYU?

After this groupwork, the ideas were discussed together, and then users returned to smaller groups to comment other group's ideas, and then vote for the best ideas to prioritize them. At the end of the workshop, attendees were also allowed to give general freeform feedback. Overall, the workshop was highly successful, as it managed to generate many ideas, and spark discussion on the ideas through attendees' ability to write comments on them. This resulted in rich qualitative textual data on MyJYU's current and potential features, which fits the purposes of this study and its thematic analysis well. However, there are also limitations. Often workshops are hard to document completely (Ørngreen & Levinsen, 2017), and in this case voice-based discussion in Zoom wasn't recorded, which means that aspects of the workshop can't be analyzed. Thus, the analysis was limited to the ideas and comments written by 33 individual participants, which is less than the total number of 50 participants invited to workshop discussions. Nevertheless, these comments include both individual viewpoints and those based on discussions of the whole groups, so it's likely that the viewpoints of the remaining group members saw some visibility, even if they didn't write them down themselves. It's also notable that while workshops can offer a rich environment for exploring new ideas, for some people the immersive, collaborative workshop environment may be a bit hectic, which may lead them to make a more passive role, affecting their responses compared to more personal research settings (Ørngreen & Levinsen, 2017). Additionally, attendees were not specifically asked to explore ideas related to utilization of artificial intelligence, although such ideas did arise organically. Thus, the data can be used to adequately support answering this study's research questions from a staff perspective, but a new study could have potentially generated more insights.

### 4.2.2 Student Survey

As noted earlier, lack of up-to-date data on student's opinions regarding MyJYU's current and potential features necessitates conduction of a new survey. Similarly to interviews, surveys can be an useful research tool when the topic of interest is people's thoughts and reasoning (Tuomi & Sarajärvi, 2018). However, unlike interviews, surveys have been most commonly used as a research method for quantitative research, but they can be also utilized for qualitative research (Braun et al., 2021; Tuomi & Sarajärvi, 2018).

While there have been concerns about qualitative surveys lacking depth compared to more traditional interviews, there are many examples of qualitative studies successfully utilizing the method, suggesting that qualitative surveying can indeed provide data that is both in rich and deep in detail (Braun et al., 2021). Typically, such surveys are conducted online, which can bring several advantages, such as respondents being able to complete the survey anytime and anywhere, and complete anonymity, although there's also a risk of excluding some groups that may not be able to participate online (Braun et al., 2021). In the context of this study, lack of computer-literacy or online presence is unlikely to exclude anyone, as the respondents are expected to be already using the MyJYU application, and the online form may actually be more accessible to some other user groups, such as people who are uncomfortable with in-person interviews (Braun et al., 2021). Due to their flexibility, online surveys often allow a larger number of respondents, potentially capturing a wider range of views and opinions, creating a more representative dataset (Braun et al., 2021). Such representativeness is highly preferable for this study, as the goal is not only capturing rich descriptions of MyJYU's usage and potential features, but also evaluating which potential features would appear most popular and should be prioritized in actual development. As the goal of the application is to serve all students, the dataset should ideally be representative of all student groups, such as freshmen, older ones who are already working, international and remote students, and for this reason it's essential that the method of data collection allows easy participation, regardless of schedule, time zone or location. It has been also suggested that compared to interviews, critical viewpoints may be easier to present in an anonymous online survey (Braun et al., 2021), which could also provide valuable insights about things that should be improved in the application. Thus, while interviewing could have also been utilized, it appears that a qualitative online survey is indeed a suitable research method for this study's needs, and is likely to capture a larger, more representative sample of viewpoints thanks to its flexibility.

In their research, Braun et al (2021) provide many guidelines for implementing a qualitative survey. Unlike interviews, qualitative surveys a fixed data generation tool, where respondents answer pre- defined questions, without possibility of clarification or further questions by researcher, making careful planning of the survey and its questions essential for successful implementation. Generally, questions should be short, open, and expressed as clearly and unambiguously as possible. It may be a good idea to group related questions together into sections. Demographics questions (such as gender and age) can be included at the start of the survey, and in the end, there may be an open "catch-all" question that allows respondents to include anything they feel is important but was not captured by earlier questions. If questions are not unambiguous otherwise, it may be a good idea to include some examples of the type of responses researcher are looking for – but at the same time, researchers should also strive not to make assumptions about what the respondents may feel or think, but rather let them express themselves openly. The length of the survey is also important – too long surveys might discourage completion or result in less detailed answers due to fatigue. Thus, the level of detail expected in individual responses, and the expected motivation of respondents should be considered when planning survey length. Instructions for completing the survey should be included at its beginning, to increase likelihood they are read. (Braun et al., 2021)

Based on the above recommendations, it appears that the many choices regarding design of a qualitative online survey are contextual – such as the appropriate length and exact phrasing of the questions. Also the sample size, expected number of respondents, can vary significantly, from a low-end of 20-49 responses to well over a hundred in a number of previous studies (Braun et al., 2021). The previous survey on MyJYU gathered 218 responses, and included a total of twelve questions, five of which were qualitative, while the rest were quantitative in nature, providing users with predetermined options to choose from. Quantitative questions were mainly utilized as leading questions, after which respondents could give more details in open-ended qualitative ones. Due to the limited time available, this survey is unlikely to gather as many responses as the previous one, but 50 to 100 responses can be seen as a reasonable goal. Despite the high number of quantitative questions, the remaining five qualitative questions on the earlier survey managed to capture rich and detailed feedback and ideas on MyJYU's features. Thus, it can be argued that a similar structure could work for this renewed survey, with four to five qualitative questions including an open-ended “catch all” question where respondents can add anything they feel meaningful that wasn’t covered in earlier responses. Although qualitative analysis will focus on these qualitative questions, a couple of quantitative ones with predetermined categories will be utilized for demographics collection, as well as to refresh respondents’ views on MyJYU’s existing features. The structure of the survey will be as follows, with quantitative questions marked with *:

1. Age *
2. Gender *
3. Years of study *
4. How much do you study remotely, how much on campus? *
5. Where did you hear about MyJYU? *
6. How long have you used MyJYU? *
7. Which existing features of MyJYU do you use the most?
8. How would you improve MyJYU’s existing features?
9. Which new features would you want for the application?
10. Do you utilize artificial intelligence (for example, ChatGPT) as part of your daily life or studies? If yes, describe how.
11. How do you think artificial intelligence could be utilized to improve the application?
12. Any other feedback?

As individual responses of a survey may be shorter than on interviews, it has been argued that data from a qualitative survey is best to be analyzed as a whole, rather than question by question, to utilize the richness of the dataset as a whole (Braun et al., 2021). This recommendation will be followed in the thematic analysis of the survey’s responses, so that responses from any question may be utilized to answer any of the research questions.

# 5 ANALYSIS AND RESULTS

As described earlier, a student survey was conducted to gather more data on student's perceptions and ideas, while existing data from a staff workshop was utilized to include staff member's perspective on the topic. Compared to the staff workshop material, which included comments written by 33 individual staff members of the 50 total participants invited to the workshop, the student survey managed to reach a much larger audience, with a total of 137 individual respondents. As described by the demographics presented in table (Table 1) below, most respondents were female, between 20 and 29 years old, and within first three years of their studies, and visit the campus at least a couple of times a week, suggesting that their studies include both in-campus and remote learning. Most of them had been using MyJYU for more than a year and use it actively at least a couple of times a week. Based on leading quantitative survey questions which were included as a part of the larger survey and the workshop, lunch menu, calendar, map, space reservation and digital library card were the features that had been used by most respondents, with remaining features seeing significantly less usage.

Table 1 Demographics of respondents of the student survey

| **Variable** | **Value** | **Frequency (%)** |
|---|---|---|
| Age | Under 20 | 6 (4.4%) |
| | 20 – 29 | 79 (57.7%) |
| | 30 – 39 | 28 (20.4%) |
| | 40 – 49 | 14 (10.2%) |
| | 50 – 59 | 9 (6.6%) |
| | 60 or more | 1 (0.7%) |
| Gender | Male | 33 (24.1%) |
| | Female | 102 (74.4%) |
| | Other | 2 (1.5%) |
| Current year of study | First | 50 (36.8%) |
| | Second or third | 51 (37.5%) |
| | Fourth or fifth | 25 (18.4%) |
| | Beyond fifth | 10 (7.3%) |
| Time of MyJYU usage | 1 – 6 months | 19 (13.9%) |
| | 7 – 12 months | 43 (31.4%) |
| | More than a year | 75 (54.7%) |
| Frequency of MyJYU usage | Daily | 61 (44%) |
| | A couple of times a week | 53 (39%) |
| | A couple of times a month | 15 (11%) |
| | Not using actively | 8 (5.8%) |

| | | |
|---|---|---|
| Frequency of visiting campus | Daily | 37 (27%) |
| | A couple of times a week | 53 (47.5%) |
| | Once a week | 11 (8%) |
| | Less than weekly | 24 (17.5%) |

The actual thematic analysis focused on remaining qualitative questions, which offered richer data on actual usage and user attitudes towards the features. Due to the research method, the number of responses, and the wide variety of them, the analysis focused on capturing broader themes that arose from many responses – rather than trying to describe every single detail from individual responses. Theory of application domains from literature review was used to guide the analysis, and to help group different subthemes under higher-level, theory-driven themes provided by the domains. Nevertheless, several themes also arose that weren't strictly related to any domain, mainly describing what makes the application convenient to use, rather than how it's used. The following sections describe these themes, separately for both current usage, and development ideas for the application.

## 5.1 Current Usage of the Application

Both responses from staff workshop, and the student survey were thematically analysed to find common themes in user's description of their usage of the application. Such descriptions can be seen a valuable source of information, because they describe the actual use of the application – rather than just features that the application has. This helps highlighting which features are commonly used, and which application domains are most served in day-to-day usage. Additionally, the descriptions also help explaining other factors that make the application useful to its users, which can have practical implications for future development. As a result of the analysis, a thematic map was formed and can be seen in figure (Figure 4) below. In further sections, themes are described in more detail, with each describing paragraph followed by translated quotes from the material analysed.

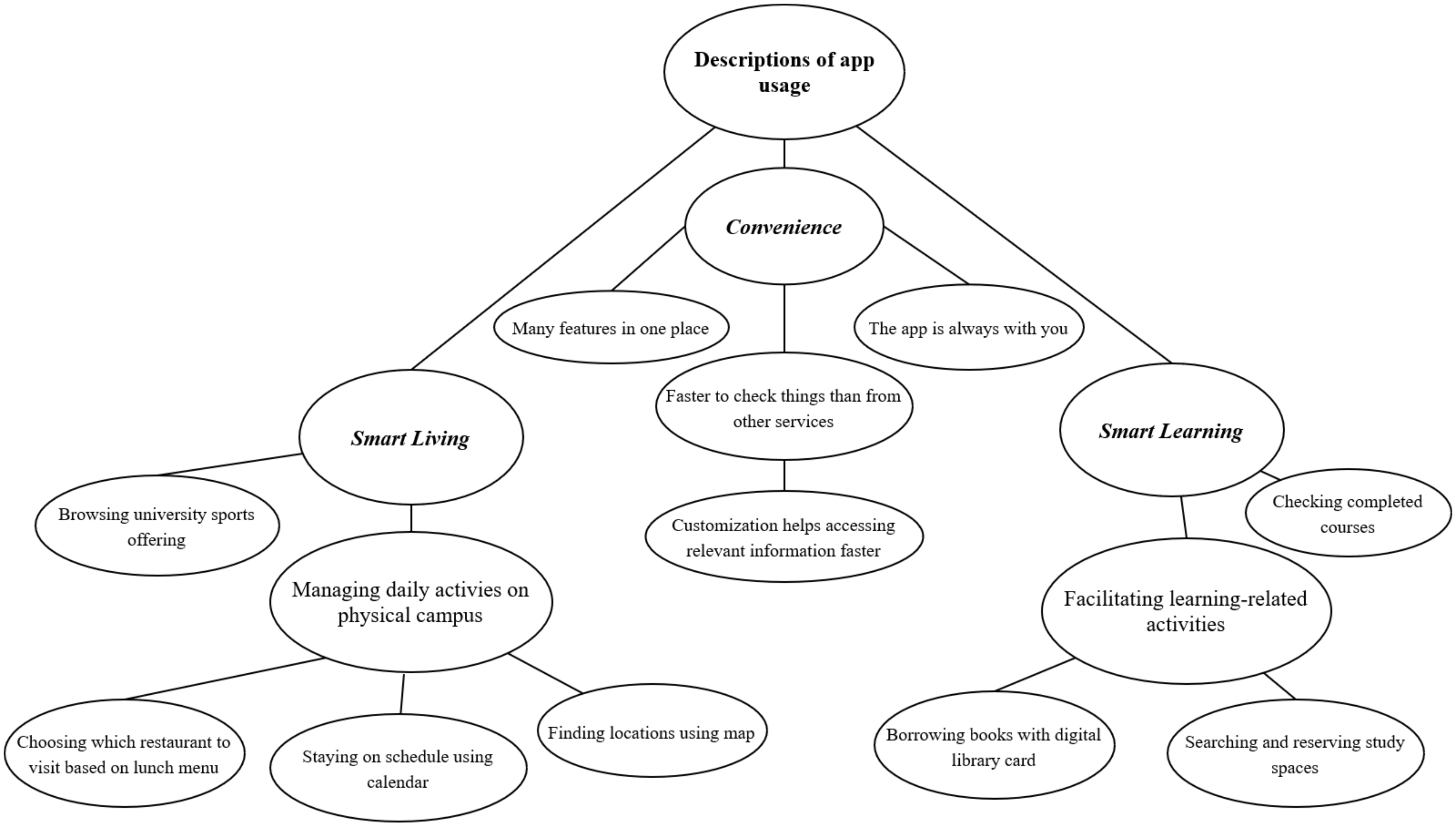


FIGURE 4 Thematic map of current usage of the application based on workshop and survey data.

### 5.1.1 Usage of Current Features and Application Domains

Based on the analysis, themes related to application domains of smart living and smart learning dominated the user's descriptions of how they currently use MyJYU. Themes related to the smart living domain were found to be most dominating, while themes related smart learning also had significant presence. Generally, students were more satisfied with the current set of features than the staff members, many of whom found the application somewhat lacking for their needs at the time of the workshop, which appears to have resulted in overall lower experience in using the application.

For most respondents, the application's primary use case appears to be managing daily activities on physical campus, making it the central subtheme under the smart living domain. These respondents typically mentioned lunch menu, calendar and map as the some of the features they use the most. For these users, the application can be seen as an assistant or a planner, which helps them get plan, optimize and get through their day while they're visiting the physical campus. Student users might check their calendar to recall where the next lecture is, use the map to find the location of the lecture, and use the lunch menu to decide where to eat after the lecture. Due to the limitations in calendar's features, it isn't widely utilized by staff members, but the lunch menu and map were found popular among them as well. In addition to these day-to-day activities, several users from both student and staff groups mentioned using the listing of university sports events to find interesting events to attend to and showing the sports ticker to prove their right of attendance, making it a separate subtheme under Smart Living. Quotes below illustrate these themes, describing which smart living related features the users utilize the most and when:

> Lunch menus are conveniently all in one place. Additionally, I check where the lectures are and what events are on that day according to the internal calendar. It is convenient to check these things on the way to the lecture and between lectures. (Student 94)

> Lunch menus so that I know if I want to eat and where. The map so that I know where I'm going, sometimes they are really strange places. (Student 93)

> Calendar, map and menus, because these are the most common of all and the information about them is needed the most. Menus are the easiest to see in the application. (Student 19)

> …In addition, you can easily show the university sports gym membership through the app, which is really convenient. (Student 28)

While a lot of application's use seems to be centered around the smart living domain and its supporting day-to-day activities, for many users the application also appears to be a tool for facilitating learning-related activities as well. As academic work and research can be also considered a form of a learning process, this central subtheme fits well under the smart learning domain, and includes the space reservation, and digital library card features, which are commonly utilized by both staff members and students. Many users reported that they frequently use the space reservation feature to reserve spaces for studying, either to get a quiet place to focus, or for collaborative groupwork, typically in library setting. The digital library card similarly appears to be popular, allowing quick borrowing of materials from the library. Additionally, several users reported using the list of completed courses to check the progress of their studies, although as a more recently added feature, its relative popularity can't be judged solely based on these findings.

> I use map and features related to reserving rooms, because study rooms are an important part of my study routine. (Student 38)

> The lunch menu and space reservation, because almost all my courses are distance learning, so I usually go on site to study and eat. The space reservation is the most useful feature, because I need to use my own space, and I want to be away from the noise. (Student 5)

> List of completed courses. You can easily see when you have received a grade for a completed course, no need to go to the learning management system or elsewhere. (Student 87)

Overall, based on thematic analysis, it appears that currently MyJYU provides most value by integrating to its users' day-to-day activities as they go through their day on the physical campus. The core activity of learning is also indirectly supported through facilitating features discussed. In contrast, many other existing features appear to see little to no use among respondents. These include several communicational and informational functions, such as list of student news and events, service catalogue, general search and jobs listing. This suggests that MyJYU is currently not providing much value as a source of general university-related information and communications, even though features with such goals do exist. Additionally, no usage related to domains of smart management and smart environment could be identified, but this is to be expected due to application's lack of features in those domains.

### 5.1.2 What Makes the Application Convenient for Its Users

As noted earlier and shown in Figure 4, respondents in both survey and workshop not only described how they use the application, but also why they found it convenient to use. From this a high-level theme of "Convenience" could be built, with several subthemes describing the ways users found the app convenient.

The most liked aspect of the application appears to be the fact that it includes many features in one place. Rather than having to check multiple different sources, such as restaurant menus, a calendar of a learning management system, and a mapping website, users can conveniently check everything from one application. This might explain another central theme which users described for their application's usage, which is simply that it's faster than the alternatives. The possibility to customize the front-page to view relevant information was also described as a source of speed in the application's use. As an additional subtheme of convenience, many users noted that the application is always with them as they carry their phone, which is an advantage compared to alternatives, such as a physical library card. Following quotes illustrate these factors that make the application convenient to use:

> I need the calendar, lunch menus and the map almost every day. The most important thing is that everything can be found quickly and easily in the same place. (Student 32)

> Lunch menus. It's nice to see everything together and not have to search on each restaurants' own websites. (Student 108)

> It is convenient to quickly look at the lunch menus. You can also see the calendar quickly. (Student 67)

> I like the digital library card, because then it doesn't matter if the wallet is left at home. (Student 99)

> … The digital library card is excellent by the way, because I don't have to worry about where it has been. (Staff 1)

Overall, it appears that a major selling point of the application is simply that it's more convenient than the alternatives, namely by grouping features that would be otherwise distributed between many systems together, and by making them accessible fast, anywhere if the user has their smartphone with them. This makes sense considering the day-to-day nature of the application's use described in the previous chapter.

## 5.2 Ideas for Future Development

As in the earlier analysis of current usage, responses from staff workshop, and the student survey were analysed to find common themes in user's ideas towards development of future features. The analysis found many feature ideas that could be mapped into application domains, as well as themes emerging from ideas for number of improvements that would generally make the application more convenient, without being tied to any application domain specifically. The full set of found themes are illustrated in figure (Figure 5) below. Again, themes are described in more detail in the following sections, with descriptions followed by illustrating quotes from the analysed material.

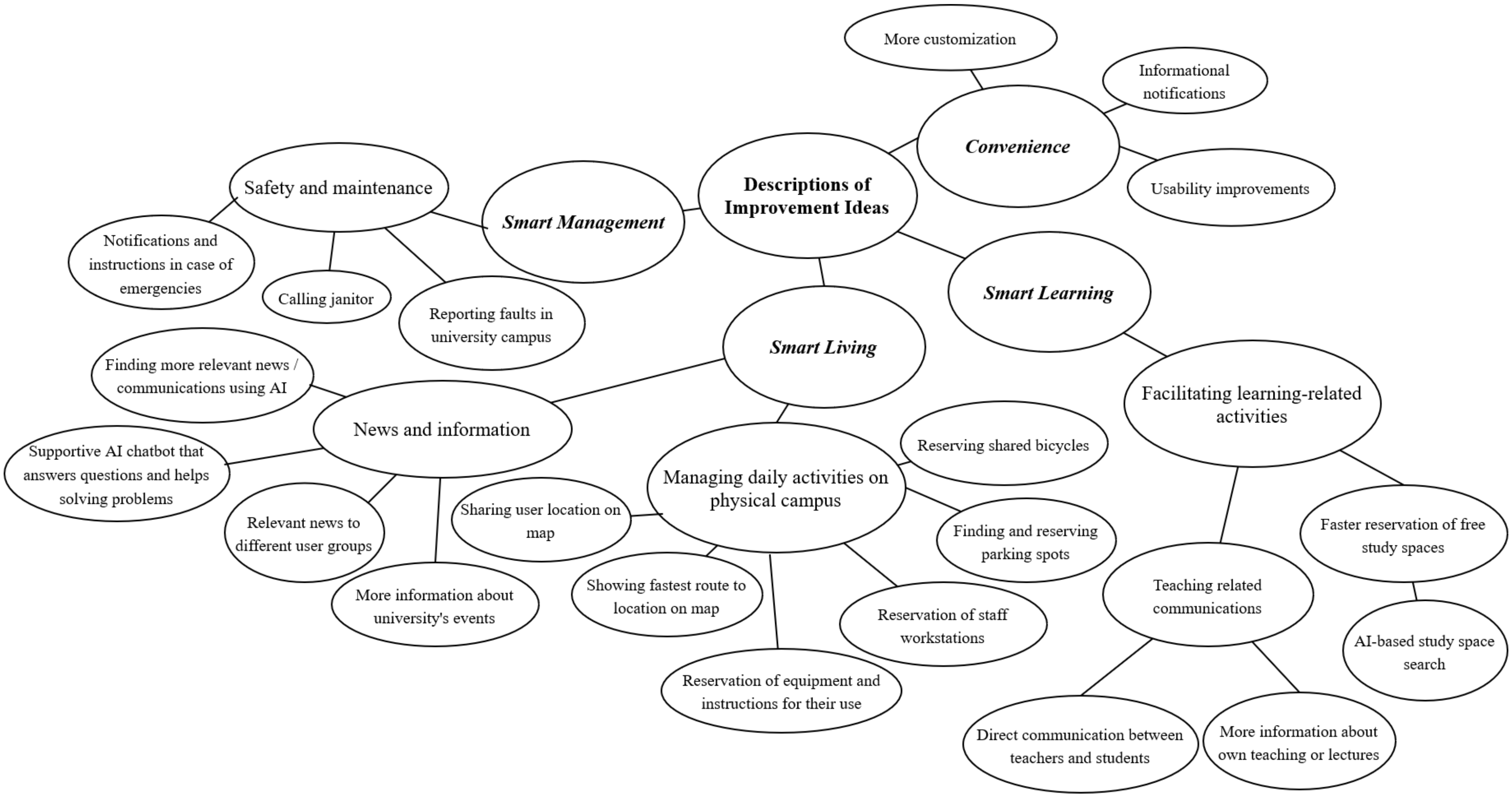


FIGURE 5 Thematic map of future development ideas for the application based on workshop and survey data.

### 5.2.1 Ideas and Attitudes Towards Future Features and Application Domains

Similarly to the thematic analysis of current usage, themes related to the smart living and smart learning domains dominated the future development ideas. However, unlike in earlier analysis, also certain themes related to smart management were identified, and in both smart living and learning significant new subthemes were discovered, including themes related to the potential usage of artificial intelligence to improve the application.

Under the domain theme of smart living, respondents presented many ideas on new features that would make the application even more useful as a tool for managing daily activities on physical campus. Themes that received particular interest among respondents were map-related improvements, such as routing and user's location, extending the reservation features to allow reserving of staff workstations, equipment, as well as improving mobility through reservable smart parking spots and bicycles. In comparison, the staff workshop resulted in more fully new development ideas related to these themes, while students were more interested in improving existing functionality.

> Showing directions on a map would be a good addition, e.g. guidance from the main doors to the desired space, either in text or navigator style. It would make searching easier, especially in completely new places. (Student 8)

> The map could include some so-called landmarks, such as exterior doors, based on which it would be easier to understand where you are when you enter the door. (Student 10)

> A positioning service, where you can make yourself and your location visible on the MyJYU map, if you want colleagues and others to find you on campus. (Staff 2)

> It would be great if you could look at MyJYU to see where there are currently free parking spots for staff! But it would probably also help if you could easily see where there are parking spaces for JYU staff. (Staff 3)

> If the university also moves to more flexible workstations, or if some already are doing this, it would be convenient to have a service here, in addition to other room reservations, that will show where there are available workstations. (Staff 4)

While application's informational features, such as news listing, saw only little use according to analysis of current usage, a role as a source of news and information was a central theme that stood out in the analysis of ideas for new features. Many respondents, from both staff workshop and student survey, wished that the application would deliver them more information about university's events and news, preferably so that the results would be relevant and targeted towards them. When queried about ideas for usage of artificial intelligence, several student respondents saw filtering of these news to offer more relevant information as one potential use case. Additionally, both staff and students envisioned integration of an AI chatbot as a useful feature, which would similarly serve these informational purposes by answering common questions and helping to solve problems. Overall, the chatbot was by far the most common use case envisioned by both staff members and students as a use case for AI.

> News and events from the intranet to MyJYU, so that both the use of MyJYU and participation in events can be boosted. (Staff 5)

> The news needs more categorization so that interesting topics don't get lost in the noise (interesting and noise are certainly different topics for different people). (Staff 6)

> The content of the university newsletter could also be viewed in the application instead of just in the e-mail. At the moment, the newsletter is such a separate thing and I think information about events could reach more people if it was also included in the application. (Student 53)

> The calendar could show the events of the student's organizations/hobby organizations I have chosen in addition to my own courses. (Student 47)

> Possibly, MyJYU could be connected to the university's chatbot or something similar, so that it could then, for example, fetch some study instructions directly or something like that. (Student 106)

> …The the application could, for example, target general communication and advertising or marketing and event bulletins directly according to the user's field of study; and could also encourage to search for a job and to pay attention to new positions opening up when they could be suitable for the student- possibly the student could fill in, for example, several job wishes marked with # on the MyJYU job page, and then receive job advertisements corresponding to # or close to them. (Student 122)

Similarly to the domain theme of smart living, also in smart learning themes related to communication stood out compared to the analysis of current usage. Among both students and teachers, there were many ideas regarding how the application could facilitate learning by allowing students and teachers communicate more conveniently, and by making course-related information more readily available. Additionally, many students hoped that the reservation of spaces could be made faster and easier, as currently the process was found to be more complex than necessary. As one way to accomplish this, several respondents envisioned space recommendation system as a potential use case for AI.

> A button for teachers: I'm free for discussion. The student can then see the location of their own teacher on the map, for example in the cafeteria. (Staff 2)

> Instant messaging to students being supervised, for example, you could easily send a message if there is an obstacle, or a student has not arrived and you could ask if they are coming. (Staff 7)

> University's / student organization's course communications should preferably be in MyJYU rather than social media. (Student 120)
>
> The reservation calendar and the search for reservable spaces is somehow beyond many steps and works clumsily. I would like some clarity on that. (Student 29).
>
> It would be easy and convenient if course communication was available through the application and not e.g. via e-mail or a learning management system (Student 78).
>
> Reserving rooms - artificial intelligence could search for suitable rooms for the purpose (Student 44).

As mentioned earlier, many ideas related to the domain theme of smart management were identified in the analysis, which wasn't the case in analysis of current usage. Most of these ideas came from the staff workshop and focused on making the application a tool for improving safety and maintenance. Ideas that gained popularity in this theme were adding notifications and instructions in case of emergencies, a feature to call janitor to current location through the application, as well as reporting faults in campus to the management.

> Instructions on how to act in an exceptional situation or, for example, in a situation of violence or the threat of it. (Staff 8)
>
> Alert button to fetch janitor as soon as possible. (Staff 8)
>
> In the case of major disturbances and situations, there could be notifications that pop up on the mobile phone somehow (for example, a power cut or a short-term ban on the use of the building) (Staff 9)

All in all, it seems that while MyJYU's users highly appreciate its current features for managing daily activity on campus and facilitating learning-related activities, there's still more room for growth in useful feature-set serving these themes. Additionally, it's evident that many users would prefer the application to take a much larger role in providing relevant information and communication, both to students and staff members, which would mark a profound shift from its current usage, where such features see very little use. The inclusion of themes related to smart management also illustrates the need for a fully new set of safety-related features, which would also include new forms of communication about safety and maintenance-related issues. In general, the staff users found the application more lacking in features than student users, indicating the need for further development of features that are found useful by them.

### 5.2.2 How the Application Could Be Even More Convenient To Use

As in earlier analysis of current usage, also the development ideas presented by staff and student respondents included ideas on how to generally make the application more convenient to use, making the case for including theme "Convenience" for grouping themes that don't map to any specific application domain or feature, but nevertheless describe potential improvements to the application.

Although the application was generally found convenient to use, various usability improvements to existing features were among the most popular topics of development ideas. Students in particular envisioned improvements to maps, space reservation and calendar to make them easier and faster to use. Many respondents also wished for useful notifications, and more customization to allow faster access to relevant and interesting information, and to hide irrelevant information.

> Publication of selected intranet news in MyJYU. Role-specific categorization of news. Push notifications for critical news. (Staff 10)

> Some course changes should be notified via the application rather than via email. (Student 72)

> Possibility to customize your own home page with e.g. quick functions. If you use the library card, map and lunch menus the most, then you would get them visible on the front page, and if you use more, for example, university sports exercise sticker, menus and completed courses, you would get them first on the front page. (Student 128)

> Maybe I would improve the ease of use of the different features and improve the map, because not all rooms (e.g. the labs) can be found on the map. I would develop the map to be better and easier to use. (Student 82)

Overall, if we reflect these themes to the those identified in analysis of current usage, we can see the ideas for making the app more convenient either match or augment the qualities that are currently seen as sources of convenience. The app is currently found to be convenient because it's somewhat customizable, and because it's faster to check things from it than from other sources. Usability improvements and more customizations could support this source of convenience, by making app's features even faster to use. Having many features in one place was another major source of convenience identified, and having more features useful to staff would clearly make it more convenient from that perspective. The note on informational notifications as a source of convenience supports the earlier findings regarding the need for an expanded feature-set related to communications and providing information.

# 6 DISCUSSION

In the literature review section, the theory of smart campus application and technology domains, based on research by Muhamad et al (2017), Chagnon-Lessard et al (2021) and Zhang et al (2022), was utilized to identify common domains served by smart campus mobile applications, as well as the technologies utilized to implement the features serving these domains. It was noted that features related to the application domain of smart living dominated existing smart campus mobile applications, with smart learning coming second, and smart management and smart environment related themes seeing relatively little usage in comparison. These findings generally align with findings of an existing survey on features of smart campus mobile applications, although that research was limited to Taiwanese context only (Cheng et al., 2017). A wide variety of technologies were found to be utilized in building the services included in mobile applications of earlier research– ranging from traditional technologies, such as databases, GPS and mobile networks, to more novel ones such as IoT-devices, artificial intelligence and augmented reality. The model of application domains was found to be useful for analyzing features of smart campus mobile applications, and thus provided a good base for the thematic analysis of university's MyJYU application in the empirical part of the study.

In the empirical study, the goal was to examine the ideas and attitudes its MyJYU's users held towards its current usage, as well as potential future features of the application, and utilization of artificial intelligence as a part of it. The results of the analysis appear to align with the findings of the literature, with themes related to smart living and smart learning dominating application's usage and ideas for it, with smart management seeing also some use interest. The analysis also shines some light into the qualities that can make smart campus mobile applications convenient to use, building on top of previous research by Lumor et al (2020). In the following chapters, the findings are discussed in more detail.

## 6.1 What Do Users Want from a Smart Campus Mobile Application and How They Use It

As a limitation, the literature review, and the large body of existing research on smart campus mobile applications mainly focused on describing what has been implemented, rather than on the human-centered viewpoint of studying what the users desire and what they use. These two viewpoints may not always align – for example, in the larger smart campus context, Zhang et al (2022) found that that the smart environment domain was more represented in ideas of students compared to its prevalence in existing research, while smart management and smart living were somewhat less prevalent than in research. Other two comprehensive studies including survey of student's perceptions also found smart learning related themes to be important, with also smart management and smart environment seeing significant interest. (Ahmed et al., 2020; Mustafa et al., 2021). By examining MyJYU as a case study, it's possible to build some understanding on how these findings apply to the context of smart campus mobile applications specifically, and whether there's a gap between features offered, the actual usage and desires of the users.

The existing case study on MyJYU noted that due to its multi-featured nature, many users use only a subset of the application's features, possibly trying and then abandoning usage of other features, or never giving them a try at all (Lumor et al., 2020). This discrepancy is further confirmed by the empirical analysis of this study – a significant number of existing features saw very little mentions in descriptions of application's usage or development ideas, while a small number of features attracted a large amount of interest. These features of interest were mainly centered around the domains of smart living and smart learning, with smart management also attracting some interest among staff members.

### 6.1.1 Smart Living – App as a General Assistant for Daily Campus Activities and General Communication

In the domain of smart living, features that help users manage their daily activities on physical campus seem to dominate application's current usage. The subdomains of smart supporting facilities and smart navigation are represented through the most popular three features – lunch menu, map, and calendar. Using these three features, users can plan and get through their day effectively. Additionally, the smart health subdomain sees some usage through sports related features. In development ideas, the subdomains of smart social, smart navigation and smart supporting facilities saw the most interest. In contrast to application's current usage, many users wished the application to include more communicative and informational features, such as relevant news to different user groups, more information about events, and an AI-chatbot that could answer questions, as well as filtering of events and news using AI. To make application even more helpful for managing daily activities on campus, users envisioned features such as sharing user's location on map, showing fastest route to location, as well as search and reservation of parking spots, equipment, bicycles and staff workstations. Most of these ideas were presented by staff members, suggesting that students might be more satisfied with current features than staff members. Indeed, some staff members explicitly stated that they didn't find the feature set of the application yet useful enough for them.

Overall, these findings support the importance of smart living domain as a target for features of smart campus mobile applications and show that the interest towards this domain in previous research is likely to align with end-user's interests as well. When considering practical implementation, it may be wise to focus first on features that users are likely to need when navigating the physical campus, as well as on features that provide them with relevant, interesting and up-to-date news or event information.

### 6.1.2 Smart Learning – Features for Facilitating Learning Activities and Teaching Communication

In the second identified domain of smart learning, the application currently appears to serve primarily a role of facilitating learning activity, rather than a tool of learning itself, with major focus the subdomain of smart learning facilities through features such as study space reservation, and digital library card. In practice, these features related to space reservation somewhat overlap with the smart living domain, as the same spaces could be reserved for non-learning purposes as well, but it seems appropriate to include them under smart learning, as ultimately, they facilitate the core activity of learning.

Additionally, as a feature of smart pedagogy, a significant number of users mention using the completed courses listing to check their progress and grades. In development ideas, users envisioned many new ways to make the application even more useful as a tool for facilitating learning-related activities, but little ideas related to making the application a tool for learning. Related to the subdomain of smart learning facilities, many users wished for search and reservation of free study spaces to be made easier and faster to use, with potentially utilizing AI to help finding ideal spaces. Similarly to smart living, many users wished for communicative features that don't currently exist in the application. These included the ability to directly communicate between teachers and students, as well as seeing more information about own teaching or lectures, both of which can be seen as features of smart pedagogy subdomain.

Again, these findings support the importance of smart learning domain as a target for features of smart campus mobile applications, suggesting that the research interest on the topic likely aligns with interests of end-users as well. As a practical consideration, it might be best to focus on features that facilitate learning, such as enabling reservation of spaces and communication from courses and with teachers, rather than making the app itself a learning platform.

### 6.1.3 Other Domains and General Implications

No current usage related to the smart management domain could be identified, as the application currently has no features related to it. However, in analysis of future development ideas many staff users showed interest in features related to its subdomains of smart security and smart asset management. Under smart security, many respondents wished to receive notification and instructions in case of emergencies, as well as the option to calling janitor quickly through the application. Under smart asset management, they wished for an option to report faults, such as broken equipment, on campus through the application. No ideas related to the final domain of smart environment were presented.

As noted by the earlier case study on MyJYU, perceived usefulness of the features is one of the most important factors positively influencing continuous usage of mobile applications, including MyJYU (Lumor et al., 2020). Based on this study, it appears that those features users find most useful for a smart campus mobile application are such that help them get through their day on the physical campus, and those that help them facilitate the core activity of learning, without making the application a tool of learning. Additionally, staff users appear to find features related to improving security, availability of help and maintenance useful, while students showed little interest in them. Staff users were also generally less satisfied with the present feature set and described more fully new ideas for features. These findings have many practical and theoretical implications.

As the first practical implication, in line with the views of Zhang et al (2022), the findings suggest that it's likely best to take a human-centered, rather than technological approach to building smart campus mobile applications. Rather than starting by implementing fancy, technologically advanced features, the most value and perceived usefulness might be achieved by first implementing a set of basic features that the users believe they need the most in their daily lives on campus, even if they are technically nothing more than integrating existing services under the same user interface. The difference between satisfaction of student and staff users on usefulness of the application also highlights the need to consider all user groups in this implementation, if the goal is to build an application serving all campus stakeholders. Ideally, these should also include those who use campuses services fully remotely, although due to demographics of the respondents, only limited insight could be gained on what features fully remote workers or students are likely to value.

Secondly, it appears that most users do not necessarily see a need for a smart campus mobile application to be a tool of learning, but they would like it to help them facilitate the act of learning. This suggests that for learning purposes it might be better to utilize existing mobile applications that are built for the sole purpose of learning activity, rather than trying to integrate their features into a common application

Thirdly, for utilization of artificial intelligence, it appears that integration of a chatbot and using AI for filtering news or events might be useful features for boosting informational capabilities of smart campus applications. Nevertheless, like with technology in all user-centric design, adoption of artificial intelligence-based features should be seen as means to an end, not an end itself, with genuine usefulness of the features being the most important factor to consider. As a theoretical contribution, this study further validates the model of application domains by Zhang et al (2022), finding significant use cases and interest towards all application domains except the smart environment domain. With the dominance of smart living and learning domains in both literature review and empirical research, this study further suggests that the focus on these two domains on previous smart campus mobile application research has likely been justified. Finally, as a further confirmation of research by Lumor et al (2020), this study suggests that the perceived usefulness of the MyJYU mobile application indeed has a significant influence on its usage, with lack of features perceived useful by staff members likely contributing to their overall lower usage of the application.

## 6.2 Which Qualities Make the Application Convenient to Use

As noted in the previous chapter and earlier research, perceived usefulness of a mobile application's features is a major influencing factor in its usage (Lumor et al., 2020), and thus how convenient its perceived. However, this study highlighted also many other factors increasing the application's perceived convenience, many of which were also present in previous research by Lumor et al (2020). These factors can be defined as the presence of multiple features, speed of use and access, usability, having the application always available, as well as possibility for customization.

In their study, Lumor et al (2020) noted that one factor supporting post-adoption use of MyJYU was its completeness, which is a result of the application having multiple features, which complement each other, and make the application useful for a wide variety of tasks. This presence of multiple features was also found to be a major reason for application's usage in this study's empirical analysis. While the features alone are not unique, together they provide an unique experience, because no other service offers all the features in the same place (Lumor et al., 2020). While the uniqueness noted by Lumor et al (2020) wasn't explicitly mentioned by respondents of this study's empirical research, many respondents mentioned the speed of using and accessing features as a major thing they like about the application. This speed of use can be seen to be a result of the unique feature-set described by Lumor et al (2020), as having many complementing features, such as the calendar, map and lunch menus under same user interface, is what makes the application faster compared to checking same information in many different services. As noted by Lumor et al (2020), ease of use is a major factor influencing mobile application use and adoption. In the empirical analysis of this study, usability and having applications always available on smartphone, unlike physical alternatives, were major themes that can be seen affecting the perceived ease of use. The respondents generally found the digital library card and sports sticker to be highly useful and more convenient than physical alternatives, and presented many ideas for usability improvements, highlighting the importance of the topic. Finally, Lumor et al (2020) noted that MyJYUs options for customization, such as showing favorite restaurants on the front-page, was a factor that made it easier to integrate MyJYU into student's everyday life, increasing application's usage. This study supports their finding, with options for customization mentioned by many respondents of student survey as something they like and utilize.

Overall, as theoretical contribution, this study suggests that general factors which influence mobile application use, such as quality, ease of use, and usefulness also apply to smart campus mobile applications, as was already noted by Lumor et al (2020). Further, this study confirms their earlier findings on customization and competitive advantage through unique set of complete features as factors positively influencing application's usage and making it faster for accomplishing many tasks than the alternatives. This study also found that sometimes simply the digitalization of a feature by including it in the application can be seen useful, when the alternative would require usage of a separate physical entity, such as a library card. As practical implications, these findings further suggest that when developing smart campus mobile applications, multi-feature application is likely to be more useful than a single-feature one, which is significant as most applications discussed in literature review appeared to contain only features from one application domain. Generally, it might be wise to think about how different useful features may complement each other and form a unique whole, rather than just focusing on individual features and their uniqueness. This way, the result may be more likely to truly integrate into its users' daily lives on the campus, rather than staying separate from it. The findings also highlight the importance of continuous testing, monitoring and improvement of features based on user feedback – although MyJYU included basic features for seeing general news and events and these themes were seen important by many users, the actual use of MyJYU as a source of news and event information was found to be very limited, because the news and events provided were found to be too general, limited and not useful for many user groups. Thus, it's not enough for features to be merely present – they should also be genuinely convenient compared to the alternatives.

## 6.3 Limitations

As in all research, it's important to consider the limitations of this study in addition to its contributions. Due to the nature of the literature review, mobile applications that have not been discussed in smart campus related scientific literature were excluded from this analysis. It's possible that a more comprehensive review evaluating also campus related mobile applications that have not been subjected to previous academic research could have yielded different results in terms of application domains, features, or technologies used. Additionally, the existing literature on smart campus mobile applications mainly focused on their features, and not user's attitudes, which further limited the understanding that could be built through the literature review. Due to the limited scope of this study, the important topic of privacy wasn't discussed, and was underrepresented in the reviewed literature as well, although the applications and technologies discussed could have significant implications in that front. While the theory of smart campus application domains was generally found useful for analyzing features of mobile applications, it also had its limitations, as usage of features could overlap between multiple domains, making categorization difficult.

The empirical part of the study also has its limitations. As the subject of the empirical study is a single mobile application used by a single university, in a single country, the results may not apply everywhere, as smart campuses of different parts of the world may have significant differences and unique needs (Malatji, 2017), and even smaller differences, such as the size of the university, its surrounding city, and traffic patterns (Přibyl et al, 2018) may affect the needs of its users. Due to limited time and resources, the study had to utilize existing material from the staff workshop, which wasn't completely up to date in relation to MyJYU's current features, which may also have omitted some useful insights. Student's insights were collected using an online survey, and as pointed out by Braun et al (2021), surveys commonly result in shorter answers than interviews. This was the case in this study as well, and while it allowed collecting viewpoints from a large set of over a hundred respondents, it's possible that interviewing would have created a richer set of individual viewpoints. It's also notable that most of the respondents visited the campus regularly, due to which few insights were gained regarding the needs of those students who study fully remotely. This bias against remote students in respondents is likely to be a result of the application's current features focusing mostly on activity in physical campus, and thus does not indicate that the application couldn't be useful for them with a different set of features. Also generally, it's likely that the existence of current features also affected user's ideas for new ones, compared to a situation where users were asked to envision features for a fully new application, which may affect the results. The deductive thematic analysis used to analyze the large amount survey and workshop data also has its limitations – while it does help provide answers to the research question, such an analysis can lose some detail when compared to a more inductive approach (Braun & Clarke, 2006). The resulting themes can be seen as a good presentation of the overall data, but not a comprehensive listing that captures the exact viewpoints of every single individual response. Finally, the author of this research has used MyJYU for several years and is also a member of its development team. This is likely to induce some subconscious biases, which may affect the results of the research.

## 6.4 Topics For Further Research

As noted in limitations, due to the demographics of respondents this study offered only limited insights into how smart campus mobile applications could better serve those who use campuses services remotely. With prevalence of remote and hybrid learning, this would appear to be a topic of significant importance for further research. The results of the study also indicated significant interest in utilization of artificial intelligence in support of the MyJYU mobile application, but actual usage could not be evaluated, as the application had no AI-utilizing features at the time of the workshop and survey. Thus, utilization of artificial intelligence in smart campus mobile applications could present another valuable opportunity for further research. Such research could be potentially conducted either as a wider survey, or as a continuation of this study's empirical research on MyJYU, as the application has since been updated with new, AI-based features based on user feedback. As also noted in limitations, application's current features are likely to have affected user's ideas for future feature development. This insight suggests a need for research that examines stakeholders' perceptions and ideas towards smart campus mobile app development in a situation where a fully new application is being developed for a campus with no existing application serving similar purpose. Finally, considering the potential privacy implications of the various discussed smart technologies and features, further research on privacy and information security of smart campuses could be useful.

# 7 CONCLUSION

This master's thesis examined features, technologies and usage of mobile applications, that have been built for the purposes of a smart campus. Through a review of existing literature on smart campus mobile applications and domains defined by Zhang et al (2022), the study was found that the application domains of smart living and smart learning appear to be most targeted by the features of smart campus mobile applications, with smart management and smart environment seeing significantly less attention. In the technology domain side, it was found that technologies from domains of mobile technology, cloud & storage were the most utilized in support of the applications, with IoT coming third, and immersive and artificial intelligence domains coming further behind.

In the empirical part of the study usages and ideas towards a particular mobile application, MyJYU, were then examined through data from student survey and staff workshop. It was found that the domains of smart living and smart learning dominate both MyJYU's current usage and development ideas for it among staff and students, with development ideas related to smart management also seeing significant attention from staff users. In the smart living domain, it appears that MyJYU provides value primarily by helping their users plan and get through their daily lives on physical campus through features such as lunch menus and calendar, while in the smart learning domain it provides value by facilitating learning activities through features such as finding available study spaces, rather than being a tool of learning itself. Additionally, it was found that staff users had development ideas related to the domain of smart management, mainly related to the improvement of security and maintenance. The findings also indicated an amount of interest towards utilization of artificial intelligence as a part of the application, especially in form of an assistive chatbot. Finally, it was found that several factors, such as speed of use, customizability, usability, and the availability of multiple features encourage application's use, validating similar findings from an existing MyJYU case study by Lumor et al (2020). As a practical contribution, this study can give insights on which things to prioritize when developing a smart campus mobile application, and on how the application can be made useful and convenient to use. As a theoretical contribution, this study builds on top of existing smart campus research, uniquely observing mobile applications through the model of application and technological domains, giving a user-centric perspective that has been lacking from most articles on mobile applications of smart campuses.

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# APPENDIX 1 STUDENT SURVEY

The purpose of this survey is to collect feedback and ideas on university's MyJYU mobile application's existing and potential future features, and to explore ideas regarding use of artificial intelligence in aid of these features. To participate, you should have at least tried MyJYU. All responses will be handled anonymously and can't be connected to the participants in any way. The responses will be utilized as part of my master's thesis investigating smart campus mobile applications, as well as in aid of MyJYU's future development by JYU digital services. Any ideas and feedback is welcome, feel free to share as many as you wish!

1) What is your age?
   a) Under 20
   b) 20-29
   c) 30-39
   d) 40-49
   e) 50-59
   f) Over 60
2) What is your gender?
   a) Man
   b) Woman
   c) Other
3) How long have you used the MyJYU application?
   a) Less than a month
   b) 1-6 months
   c) 7-12 months
   d) Over a year
4) In your typical week, how often do you visit university's physical campus?
   a) Daily
   b) A couple of times a week
   c) Once a week
   d) Not at all
5) How often do you use MyJYU?
   a) Daily
   b) A couple of times a week
   c) A couple of times a month
   d) I have tried it, but don't use it actively.
6) Which of MyJYU's existing features have you used before?
   - Lunch menu
   - Favourite restaurants
   - Map
   - Searching for free spaces on map
   - Space's reservation calendar
   - Space reservation

- Digital library card
- Sisu calendar
- QR-code reader
- Vasara-process
- List of completed courses
- Student news
- IT news
- Events page
- uMove sports
- Jobs page
- Service catalogue
- Freshman's Todo
- General search

7) Which of these existing features do you use the most? Why do you find them useful?
8) How would you improve these existing features? Any ideas are welcome!
9) Which of the following activities would you want MyJYU to help you with in the future? Choose maximum of 5 most important activities.
   - Studying in-campus
   - Studying remotely
   - Schedule management
   - Transportation
   - Navigating the campus
   - Interacting with physical spaces and their devices in campus
   - Taking care of health and well-being
   - Socializing with other students
   - Other – please specify
10) What new features would you want for the application? Try to describe in detail what these features would do, and how they would benefit you.
11) Do you utilize artificial intelligence-based services (for example, ChatGPT) as part of your daily life or studies? If yes, describe how.
12) How do you think artificial intelligence could be utilized to improve the MyJYU application, including existing or new features? Any ideas are appreciated!
13) If you have any other feedback or something you may want to add, please share it here.