Conceptualization of Digital Twins in an Education Services Environment: A Straw Man Proposal

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Abstract

Digital twins have been used in manufacturing to describe, predict, and prescribe responses to complex problems. The digital twin is a constellation of technologies that mirror physical objects in the virtual world, including what has happened, is happening and could or should happen in the future for the mirrored object. What is common in previous conceptualizations of digital twins is that there is a physical boundary to the extent that digital twins can mirror real objects (sometimes including the objects' environments). We propose a blended approach, using McKinsey's straw man and Parmar et al.'s. (2020) framework, to offer a more rigorously structured process for arriving at a refined conceptualization of digital twins in the educational service environment.

Keywords: digital twins, service environments, education

1. Introduction

It has become normal for organizations to seek strategic advantages from leveraging digital transformation. This requires organizations to have both the capacity and capabilities to self-evolve and anticipate current and future changes rather than being reactive (Berisha-Gawlowski, Caruso & Harteis, 2021). Digital systems and the data they generate can provide opportunities for organizations to understand how they deliver their services, and to predict and prescribe how they could respond to complex, yet necessary changes that could provide strategic advantages. Often, this requires tools for testing ideas and assumptions before full deployment of changes in processes, practices, technologies, and other facilities that organizations use to deliver services. The ability to test hypotheses in near-real time without disrupting the real-world value creation environment makes *digital twin technology* a very attractive proposition for organizations in various sectors, including manufacturing, healthcare, transport, energy, and infrastructure. Previous research shows that many organizations, particularly in the manufacturing sector, see digital twin technology as means to realize significant commercial benefits by enhancing the experiment space that informs improvements in such areas as operations, product, and service innovation.

Digital twinning seeks to bring together the best features of planning, simulation, forecasting, and big data into a cohesive digital artefact that can be used to provide a digital representation of reality.

The term "digital twin" has long been used to describe a virtual, digital equivalent of a physical product (Zhang, Ma, Sun, Lin, & Thürer, 2019) and a connection between a virtual object and its physical counterpart (Van der Valk et al., 2020) such as between digital cars, aircraft, buildings, or even cities, and their physical equivalents. Such a connection requires that various data be collected in real-time, from the physical object to its digital mirror or twin (Glaessgen and Stargel 2012). This includes data such as: sensory data, granular "atomic" level data, geometric data, current, past, and predicted data (Grieves and Vickers 2017). A high level of synchronicity is also important as it enables the digital twin to maintain an "ultra-realistic" version of its physical counterpart (Glaessgen and Stargel 2012). This, in-turn, means that a digital twin requires highly durable systems support for handling high frequency and high velocity data (Rathore et al., 2021).

The digital twin is a constellation of technologies that mirrors physical objects virtually, capturing data about what has happened, what is happening, and/or what could or should happen in the future for the 'twinned' object. For example, every Telsa car, or aircraft developed by GE has a digital twin (El Saddik, 2018; Saracco, 2018). These products report back to their parent companies daily, about their experiences and such data are used by simulation programs on the digital twin to discover anomalies and provide corrective actions. The multitude of digital twins, for Tesla as for GE, makes possible to learn from multiple experiences. For example, Tesla, Inc. indicates that it gets the equivalent of 1.6 million miles "a day" of

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driving experience and this is fed back to each car in a continuous learning process (Saracco, 2018).

While simulation certainly is a central aspect of how digital twins work, particularly though predictive capabilities (Van der Valk, 2020), digital twins are more than simulations in that they do not necessarily carry intentionality, but rather, they indiscriminately capture real-time data about the functioning of an object, such that even unintended events, anomalies, and discrepancies between intended design use and actual use can be captured. This tells us how something that was designed is being used, which goes beyond forecasts based on use, or predicted use.

Manufacturing was quick to leverage the benefits of statistical process control in the first half of the 20th century (Shewhart & Deming, 1986) and services caught up in the later part of the century. For example, applying lean six sigma to services is now a relatively normal practice. A similar situation is unfolding as manufacturing has been seeking and optimizing their value creation processes with digitalization and digital twins representing the current state of the art. It seems only logical that the service sector will seek to learn and capitalize on that knowledge base as it has done before.

2. Background to Digital Twins

In the following discussion, we describe the context of digital twins in manufacturing and explain why this becomes challenging when extended to a services setting. We focus on education services as a use case and identify the research gap explored in this paper.

2.1 Digital Twins in Manufacturing Industries

In the field of manufacturing, digital twins are at the heart of creating cyber-physical systems (CPS), which integrate physical and digital components (Tao et al., 2019). In such cases, a digital twin serves as a virtual mirror of the physical system. For example, such systems have recently been implemented to capture and mirror developments in cities (Ketzler et al., 2020), automotive industries (Biesinger & Weyrich, 2019), and production lines for other physical products. The digital version is often used to track how well the physical product is running, collect data about experiences in its use, and possible inefficiencies, without necessarily affecting the use of the physical/CPS version (Figure 1).

Digital twinning is also used to carry out simulations to create representations of the physical system that integrate these two parts, physical and cyber, to a full closed loop control system in which the physical system is controlled by the virtual one.

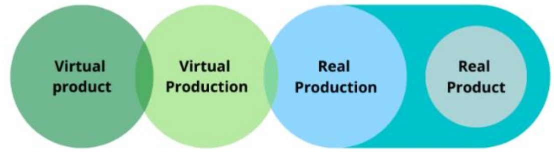

Figure 1. Cyber-physical progression of a product cycle using a digital twin

2.2 Digital Twins in the Services Context

What is common in previous research on the application of digital twinning in manufacturing is that there is a physical boundary to the extent that digital twins can mirror real objects (sometimes including the objects' environments). There is, however, a noticeable trend in the application of the term in service environments such as health care services, education, and financial services (cf. Elayan et al., 2021; Liljaniemi & Paavilainen, 2020; Sepasgozar, 2020), where such services do not have a clear-cut physical boundary. The services are often delivered through multiple digital systems and services. For example, imagine trying to mirror the information services offered to a patient in primary care: Would the patient record be the main artefact to be "twinned"? Would this also include the clinical services information involved? What of the drug administration from pharmacies, and the associated records? What about insurance services? What model of digital twinning can be applied in such a scenario? The same can also be said for education services, social services, and so forth.

As such, digital twins in services environment must encapsulate several fragments of a "defined service" or "service agent" or "client". This includes parts of systems that collect data about such a service, agent, or client. In a way, each actor, client, or agent in the service environment can have several fragments of their digital twin generated through data collection by various information systems. For example, social media platforms such as Twitter, Facebook, and Instagram, all collect parts of an individual's "self" attributes (e.g., preferences, choices, and interests). Governments and local authorities also collect other parts, and so do systems such as education, healthcare, and department stores (club card systems, transaction histories). Similarly, companies where individuals work collect personal information that can easily profile an individual's unique characteristics.

Moreso, unlike machine agents such cars, airplanes, robots, and other inanimate gadgets often twinned in the manufacturing industry, human agents are the key actors twinned in the service context. Twinning human agents introduces subjective elements of human behavior that are quite complex. This includes unpredictability, changing human interests, choices, and decisions; all of which makes digital twinning in the services context a complex problem.

Until recently (and in some ways this remains so), all these fragments are dispersed and there exist laws and regulations on how such information can be shared across multiple agencies. Services and their supporting IT systems are often dispersed and based on actor-to-actor interactions that can change depending on the situation. This makes it complex to use digital twins as they are traditionally applied in manufacturing. The complexity of embedding a digital twin is therefore dependent on the nature of the service targeted. The original conceptualization of digital twins may not necessarily fit into such service environments where the original "mirrored" entity is not physically bound and exists as a conglomeration of multiple data and information systems (see Table 1). Thus, a unified definition and (re)conceptualization of digital twinning that considers the services environment is required.

Table 1. Comparisons between digital twinning in manufacturing and services contexts

Manufacturing Industry	Services Context
Tightly coupled systems often integrated as part of a product	Multiple independent systems from which the digital twin can be created
Object of interest is physically bound	"Object of interest" may span multiple organizations with different access rules
Machine to machine interaction is more prevalent but human to machine interaction is also present	Human to machine interaction is more prevalent but machine to machine interaction is also present
Boundary of the real object is clear cut (easy to identify)	Boundary of the real "object" is difficult to define – often intertwined with other "objects"

2.3 Digital Twins in Educational Services

Education is a service sector that must operate at considerable scale, generates large volumes of transactional data, and requires many touchpoints for funders, providers, consumers (a.k.a., students), and their support agents. As such, education is to us a brilliant natural laboratory to explore the use and issues with digital twins in a service context.

There is limited research that has explored the use of digital twins to augment the delivery of education services. Previous research related to education tends to focus on digital twins of engineering and architectural concepts used for learning (cf. Liljaniemi & Paavilainen, 2020; Dai & Brell-Çokcan 2022), but this does not directly address broader service delivery itself.

We draw conjectures from manufacturing and organizational research (e.g., Biesinger & Weyrich, 2019; Berisha-Gawlowski et al., 2021) that there are benefits of applying digital twins to educational services. On the organizational side, there is an opportunity to firstly review systems architecture or structure to identify how the systems are structured to both maintain a record of the student and deliver learning. Secondly, to identify the hierarchy of systems following systems or data life cycle of the student journey and of university processes. Lastly, there is also an opportunity to enhance data collection and analytics performed by the education services providers.

Creating a digital replica of, (a) the student's digital footprints as they traverse an educational system, (b) the record of a student's interactions (touchpoints) with an educational system is unique because it captures nuances from distinct systems that are often disintegrated. A student may leave digital footprints even though they have not specifically interacted with a system, for example, logging onto Wi-Fi and entering a building are not typical touchpoints in the way that an information request or enrollment in a course would normally be tracked.

2.4 Research Gap

The existing literature is sparse when it comes to information systems use for service delivery in higher education. Digital twins can inform how certain information systems will perform under various economic, environmental, and social conditions, and identify the drivers of possible disruptions.

The nuances of human experience and culture are beyond the scope or unable to be interpreted by the typical instruments for data collection (such as sensors and post-hoc data extraction from settings such as Wi-Fi access or building security systems) in digital twin scenarios. Perhaps in the future AI based video agents will be able to read visual cues while people are interacting with avatars, but for now, sensors and data collection approaches are limited to relatively crude measures. The point is that understanding these human complexities and their dependencies on underlying data use policies can provide detailed insights for managing educational services. Therefore, to unpack this complexity in the educational services setting, we firstly specified the heuristics for developing a digital twin in the educational services environment. Secondly, we made use of an exploratory vignette to explore the conceptualization of digital twinning in this context. This combined approach used traditional consulting techniques scaffolded with theoretical foundations. This is fully discussed in the following section on methods.

Our exploration was guided by the following research question: ***How can the concept of digital twinning be developed in an educational services context?***

3. Methods

To explore how digital twinning can be developed in an educational services context, we utilized the straw man proposal process as an expository tool. We adapted McKinsey's *Straw Man Proposal Process* (Think Insights, 2022) by blending it with the principles and evolutionary process model for building a digital twin put forward by Parmar et al. (2020 p.732).

3.1 McKinsey's Straw Man Proposal Process

The straw man proposal process (see Table 2) has previously been used by researchers as a methodological tool that provides a framework for design modelling and theorization (Cantalupo et al., 2018). For example, researchers have used the straw man proposal when they have conjectures about how a new system, process, or solution might work, and wish to give themselves and others a model to challenge and evolve (cf. Veeraraghavan & Reisslein, 2011).

Applied in previous research the straw man approach provided an opportunity for researchers to conduct multiple iterations, tear apart initial ideas, and rebuild on their initial theorization. The straw man proposal has also been used to formulate and evolve hypotheses with limited data before full-scale quantitative tests can be performed (Hattis et al., 2002). As a methodological process, the straw man approach is also used in applied industrial research and consulting (e.g., by companies such as McKinsey and Intel, cf. Cantalupo et al., 2018; Think Insights, 2022). Used in this paper, the straw man approach offers a useful starting point for conceptualizing digital twinning in the educational services environment.

Table 2. McKinsey's Straw Man Proposal Process

Step	Description
1. Concept	In the first stage of the straw man proposal process, an idea to resolve a particular challenge is raised with a consulting team.
2. Discuss	The team critiques the proposal, detailing arguments for and/or against the concept. This may lead to deconstruction or reconstruction of parts of the concept at this stage.
3. Clarify	The process continues in the 'clarify' stage, where feedback and criticism begin to shape the next iteration of the concept. The previously identified arguments are tested against this new conceptualization to confirm its suitability for the challenge at hand.
4. Decision	The proposal is then finalized. The goal is to evolve a draft concept into a version which carries the full support of all consulting members.

3.2 Principles & Evolutionary Process Model for Building a Digital Twin

As we needed structure to our proposal process in a way that considers digital twins as the object of interest, we blended the straw man proposal with Parmar et al.'s principles and evolutionary process model for building a digital twin (see Parmar et al., 2020 p.732; Figure 2). Although Parmar et al.'s (2020) focus was on the process for developing digital twins in the manufacturing context, the logical organization of these principles was applicable and helpful in structuring our conceptualization process. Below, we outline the principles and how we applied them in this study.

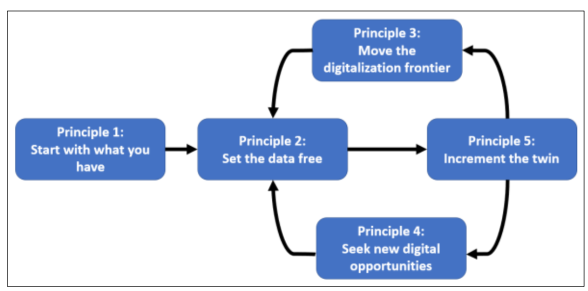

Figure 2. Parmar et al.'s principles and evolutionary process model for building a digital twin

1. Start with what you have

This principle would normally require undertaking a comprehensive audit of information systems, data collection points, and the student experience, to create an initial model of the digital twin. For this exercise, this step is carried out in sketch form only but should still capture the essential touch points of the interaction.

2. Set the data free

Much of the data collected though information systems in the University's enrollment processes is captured in "silos". To successfully create a digital twin, data needs to be "set free" from their respective silos. This can also become one of the value-generating functions of a digital twin; so, the more integrated the twin is, the more useful it can be. Therefore, improving the accessibility and opportunities to analyze data in timely manner.

3. Move the digitalization frontier

There are some stages in most enrollment process which are only partially digitalized. To realize the full potential of a digital twin, we must actively seek out those stages and digitalize them. Data generated in these newly digitalized stages should be integrated into the organizational model, so that the twin can more accurately represent its "real-time" twin. Service designers have an important role to play at this stage.

4. Seek new digital opportunities

As the twin evolves and continues to be improved upon, new opportunities emerge for how the twin can be used for organizational improvement. In sum, the insights generated from the twin can *"identify and execute new digital opportunities to further extend the reach and coverage of the digital twin"* (Parmar et al., 2020 p.16).

5. Increment the twin

This principle provides an opportunity to reflect on learnings, incorporating them in iterative feedback, before moving the digitalization frontier and seeking new digital opportunities. The expectation is that a digital twin will create a virtuous loop where new products and services can emerge because learners, educators and institutional leaders can gain deeper understanding of what, how and why some educational services are successful whilst others are not.

3.3 The Adapted Methodological Approach

Our blended approach provided us with a framework to structure to our proposal process, framing digital twins as the object of interest (see Figure 3). We were able to offer a more rigorously structured process for arriving at a refined conceptual model for digital twins in the educational services environment. In doing so, we took a concept in need of exploration and development, then simultaneously explored the feasibility and scope of that concept in a bounded context and outlined how the concept could be actualized. Our use of this blended approach in the educational services environment is a novel approach that extends previous applications of the straw man proposal process and Parmar's principles and evolutionary process model (see Figure 3).

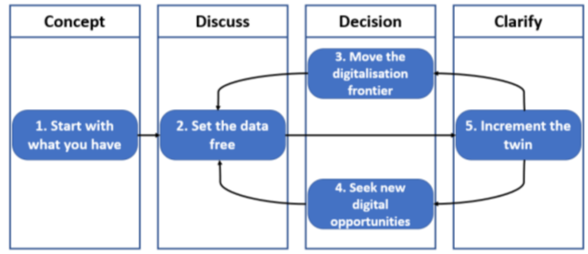

Figure 3. The adapted and merged model

In the 'concept' stage of the straw man proposal, we ***'start with what we have.'*** Here, we derived our initial straw man concept from a roundtable brainstorming activity involving four participants: (1) a senior tutor working with student learning systems (2) an associate dean - students, (3), a program director and (4), an administrator. We selected these participants for the expert panel because of their knowledge of student journeys and of the various systems and datapoints created in these journeys. This 'conceptualizing' process was underpinned by our assumption that a digital twin can be successfully created that mirrors educational services delivery.

In the second stage, 'discuss', we ***'set the data free'*** through a use case. The 'use case' we selected focuses on the journey of a post-graduate student enrolling at a university. This use case was selected as an example because it is one of the more straightforward enrollment processes. Any university enrollment process is represented by a complex set of use cases. For the purposes of this exercise, we deliberately choose one of the more tightly bound cases to help manage the scope and create clarity on the concept of DTs in the educational service environment. The use case highlights the key information system touch points (i.e., where the prospective student generates data at each step of the enrollment journey). Discovering these touch points requires document and process analysis. We paired our use of a case with document analysis of an interactive *Student Orientation Module* developed to give a procedure advice to students enrolling in a Master of Information Studies (MIS) program. As we navigated this enrollment process, we noted the information a prospective student was required to supply, and the various information systems a student would interact with on the journey.

In the next stage, we use the insights gleaned from our discussion to (re)conceptualize our initial digital twin concept. In clarifying the concept at this stage, we also delivered building blocks for nascent theory in the digital twinning conversation, in the form of an ***incremented digital twin concept***.

In the 'decision' stage, we merged principles 3 and 4 of Parmar et al.'s (2020) framework; ***'move the digitalization frontier'*** and ***'seek new digital opportunities.'*** We structured our 'decision' as a discussion of our findings (Section 5) to reflect on the learnings from our straw man process and finalize the proposal. In this stage, we also discuss the benefits, applications, challenges, and limitations of our digital twin concept.

4. Findings

The expository process we followed enabled us to identify key elements for developing a digital twin in the education services context. We also made progress on illustrating how these elements could be organized (see Figure 7) to capture data during interactions with key agents and how this can create a feedback loop that continuously improves services whilst informing the key actors (students and services providers). has revealed that digital twins in a service science context general and education specifically is a domain warranting further exploration.

4.1 Conceptualization

Our initial conjectures were that a digital twin in the higher education context we examined would heavily rely on the interaction of two agents (pursing self-agencies): (i) that of the student and (ii) that of the institution providing the services through various personnel. To interact, these two human-centric agents would use learning platforms and rely on the capture and (re)use of data to inform each other on how they were progressing in the learning journey (see Figure 4).

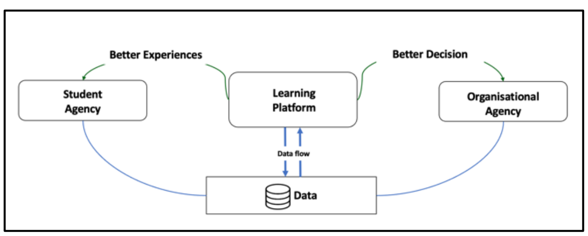

Figure 4. Initial "straw man" concept

We present our straw man in (Figure 4) as an initial digital twin concept that links students, their experiences, and touchpoints with learning platforms, capture of experiential data, and feedback for decision making to both students and education services providers. Thus, there are opportunities for the agents in our model to have constant feedback based in their experiences and make better decisions that shapes their agencies. This creates a reinforcing cyclical feedback loop starting with initial agency, experience and touchpoints with learning platforms, data capture, and feedback

4.2 Discussion

The initial straw man model we developed (Figure 4) identified weaknesses and areas of improvement to present a better conceptualization. To do this, we made scenario analysis using use cases to examine the agency of the two main actors in our model (1) the student, and (2) the education services provider(s).

We constructed a use case of a student enrolling in the MIS program. We present two perspectives of this case from our analyses. [Appendix A: Use case diagrams. Figure 5 (Use Case 1) models the student and their touchpoints with systems in the enrollment process (including data generated at each of these touchpoints). Figure 6 (Use Case 2) models the student's interactions with people in the enrollment process]. These two perspectives capture the enrollment experience in the MIS program and reveal new insights to further the development of our straw man. Using use cases in this way revealed the student's experiences and agency (decision making, mistakes, etc.) which changes the shape of the digital twin as it grows.

We recognize our assumption that data collected throughout the enrollment process will be accessible to the twin in real time, as necessary to inform the enrollee experience and decision-making capability. We assume these data may be held in a data lake. However, with the turn to cloud-based systems, data collected through the touchpoints with the University website, enrollment system, finance system, student records and so forth, may be held separately by service vendors, or may be subject to confidentiality or privacy concerns which might otherwise impede the twins' access.

Secondly, our current twin conceptualization assumes the student's pathway through the enrollment process follows the most logical and rational order, with a determinate number of decisions available at each stage. The student may make choices along the journey, such as not checking their email or returning their offer of study, which might prompt background processes to generate further touchpoints as university staff (or systems) intervene. These potential background processes are invisible to us as we explore our use case from a student perspective. A key insight here is that the structure of the twin (including the sources of data informing the twin) are shaped by the choices of the student, as it is not pre-determinable what the enrollee will do or when they will do it (despite that we know what they should do and when they should do it). A further insight is that the twin in this context will always reflect the student perspective, and as such there will be certain ‘black box’ systems which might shape the student journey but may not otherwise be “modellable” in an educational services twin. A clarified twin concept should recognize the complexity of apparently simple interactions, allowing for new data sources as the twin mirrors the student and increments itself.

Our use case analysis also highlights a key strength in our concept, which is that the role of student agency and experience is promoted as a main actor in their education journey. An incremented digital twin in this case should elaborate on student agency which may influence future iterations.

4.3 Clarification

Based on our critique of our initial straw man concept, we clarified how the digital twin can be applied to the education services in the case that we explored (see Figure 7). We observed that, unlike the application of digital twins in manufacturing (Figure 1), we will not get the same results from the same processes and procedures because of the effect of student agency and human complexity at the various touchpoints. We can improve the “experiences” for both the institution and the individual student by exploring how individual preference influences the digital twin. We present our clarified digital twin to offer deeper insight into the elements of an educational services digital twin in this context. This incremented twin captures the reality of a twin existing in a digital space, capturing data from systems determined by necessity (for example, accessing the learning platform during a course) and because of student agency (such as the additional touchpoints generated by an individual student’s interests or decisions). The digital twin also improves management and operational activities on the organizational side, as it delivers descriptive, predictive, and prescriptive analytics.

This clarified digital twin better captures how an implemented twin will increment itself to continually deliver insights about its proxy.

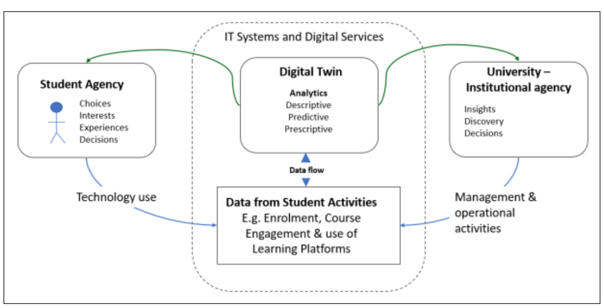

Figure 7. Revised straw man, i.e., second iteration concept

5. Discussion of Findings

In this section we discuss insights delivered from our straw man process and arrive at an answer to our guiding research question: *How can the concept of digital twinning be developed in an educational services context?* We also propose avenues for developing further research in the form of moving the digitalization frontier and seeking new digital opportunities.

Incrementing our twin in the ‘Clarify’ stage of our adapted methodological approach delivered important insights about the general applicability of digital twins in the educational services environment. Firstly, we extend on findings from the literature and discover that a further important difference between twins in service contexts and twins in manufacturing is– in the case of the latter, that the object of the twin does not have agency which fundamentally shapes the twin. This finding represents a valuable insight: this exercise demonstrates that further research exploring this concept, while challenging, represents an important opportunity for service improvement.

Our incremented digital twin conceptualization also revealed limitations of twinning in the educational services environment more generally. We learn it is not possible to have a perfect digital twin as, unlike cars and snack foods, we are not able to control all the variables that influence student behaviors through systems. There is no easy answer to explain why students choose to behave in the way they do when they interact with university systems. Often the factors and reasons are as complex as the people themselves.

Having a digital twin of an educational journey can provide further insights and access to data at individual, group, and institution levels of analysis. At the individual level (the student) a digital representation of their education context can be used simplify complex encounters, provide near real time data to enhance student agency and autonomy. At the group academic educator level digital twins can be used to model cohorts, observe behavioral trends of a group, and provide rapid insight for agile and effective systems. At the institutional level, digital twins can give rapid and accurate insights into asset utilization and management, student success and completion rates and provide visibility into aspects of educational processes that would have otherwise been lost in the noise of a complex service environment. What we can do is explore the processes the students engage with. Instead of a true digital twin the process becomes a proxy that may indicate where touch points are necessary.

Rather than a strict conceptualization of being a digital identical twin the metaphor may well be that of a digital fraternal twin – made of the same stuff but not quite identical enough to be an exact analogue – they still have something to tell us about the journey, but so many things we can't control for.

6. Limitations and opportunities

The "straw man concept" used in this paper (Figure 7) is exploratory in nature. The straw man approach is applied to deliver an interesting and logically sound concept as its end goal. Therefore, this examination of how the digital twin concept typical in manufacturing and physical goods can be applied to services generally and education. We do not claim this to be a generalizable design template. While the outcome of our conceptualization exercise is necessarily tentative, and therefore limited, we also believe that it provides a useful starting point that will provoke and inform future rigorous research in this area.

Currently, the Parmar et al.'s (2020) guiding framework is not a series of testable constructs. A Critical Success Factor (CSF) analysis could be used to move the framework from principles to constructs that could be used to develop an empirical model.

We expect to move forward with iterations that involve extensive data collection and experimentation to further develop our concept into testable and scientifically applicable models, ontologies, and design science proposals. Future work will also require a more grounded capture of rich data from student experiences as well as explication of criteria and specifications for constructable IS artefacts. This will be paired with experiments that confirm our assumptions and speculation about the value that can be derived by creating both students' agency and improved decision making for education service providers.

Apart from our own research program on applying digital twins to education services, we hope that this paper establishes a trajectory for future research by others.

7. Conclusions

This paper has shown that initiating a digital twin in educational services can help with identifying problems and gaps in systems that students interact with on campus. Digital twins in education may become a useful tool at the individual level for enhancing student agency and to help to build student autonomy through university processes. For administrators, identifying areas where students need advice and assistance can lead to better services and staffing. In addition, digital twins can be used to collect data for critically analyzing the systems and processes of the wider education delivery system.

The use of digital twins in services is still new. The focus has mostly been on its application in manufacturing. Thus, in services industry such as education, research literature is understandably sparse. The intent of this paper is to provide a stimulus for conversation about digital twins in services generally and in education services. To give ourselves and others something to react to we used the straw man approach to provide a foundational illustration of what is possible using one modest use case from the large corpus of uses cases typically to be found in any university.

By engaging ourselves with the digital twin concept we have modelled user interaction and feedback that can be generated and used for decisions. The digital twin opens-up to the possibility of integrating real-time student experiences in computational decision-making processes and thereby get immediate localized information to and about specific individuals, cohorts, and teachers which considers their current university pathways, schedules, preferences, and experiences.

On the organizational side, there is an opportunity to review systems architecture, processes, and organizational structure to identify how the systems create, retrieve, update, and dispose of data about and for students.

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9. Appendix A

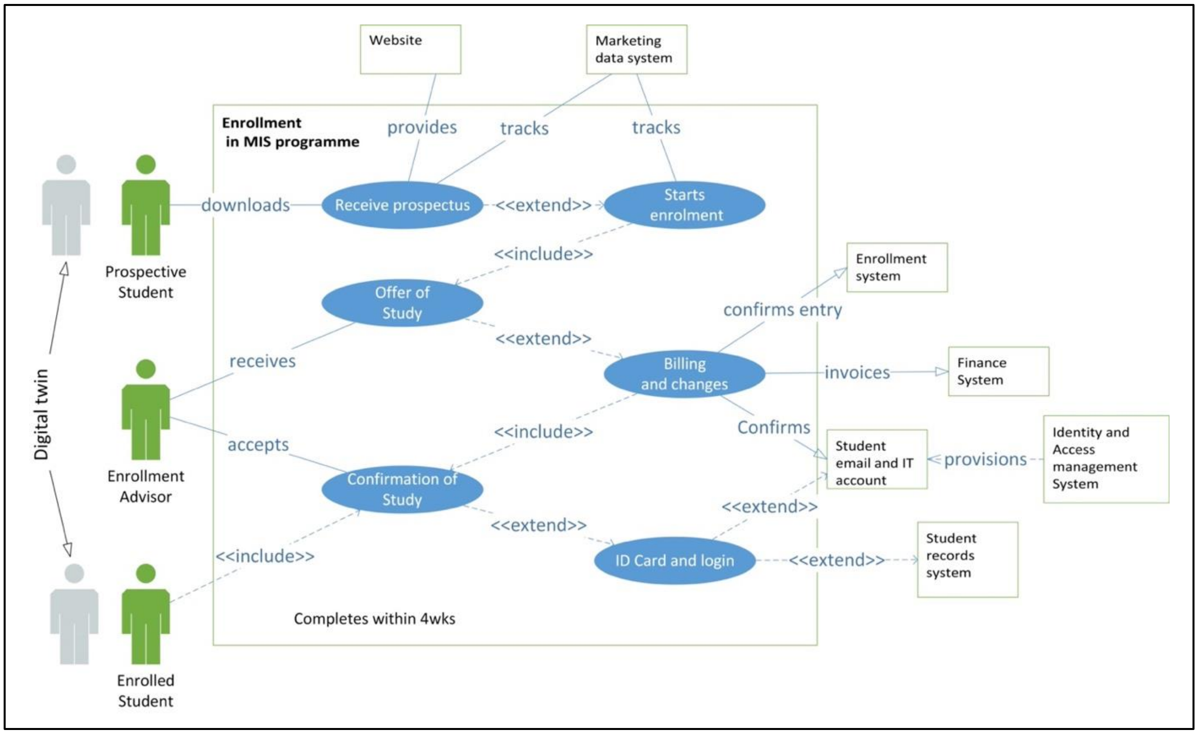

Figure 5. Use Case 1

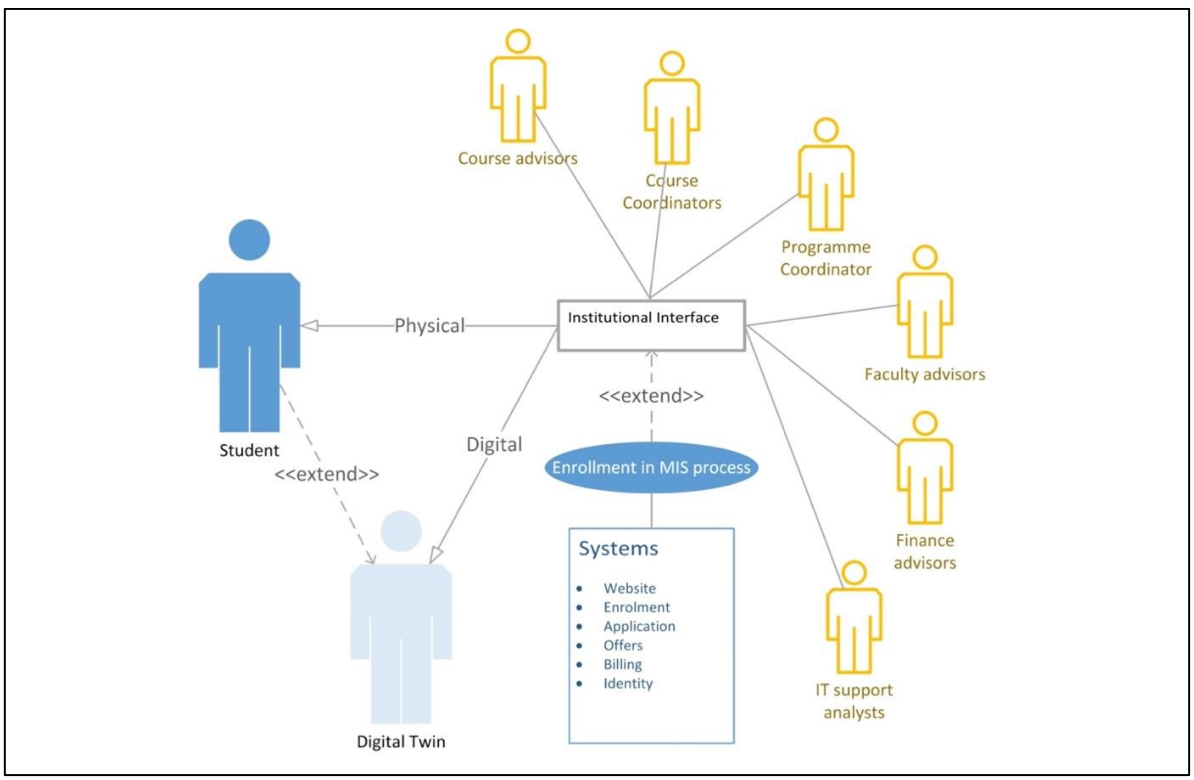

Figure 6. Use Case 2