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Knut Hinkelmann

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Preface

It is with great pleasure that we write this foreword to the Proceedings of the 4^{th} International Conference on Society 5.0 held from 26 to 28 June 2024 in Mauritius. The Society 5.0 Conference 2024 is hosted by the University of Technology in Mauritius, supported by the University of Pretoria, South Africa. This multi- and interdisciplinary conference is continuing to grow into a premier international conference series and is jointly organized by the University of Pretoria (South Africa), the FHNW University of Applied Sciences and Arts Northwestern Switzerland, the University of Camerino (Italy), the Universidad EAFIT (Colombia), the Business School of the Shenzhen Technology University (China), the Universiti Malaysia Kelantan (Malaysia), and Putra Business School (Malaysia).

We are living in an era with technologies available for software, hardware and data interconnectedness that are, and will, dictate the agenda for the future creating both challenges and opportunities for a Society 5.0. No doubt, words echoed in the New Delhi G20 Summit like the need for Creating a more Inclusive World, Driving Gender Inclusive Climate Action, Bridging the Gender Digital Divide, Harnessing Artificial Intelligence responsibly for the Good and for all have set the agenda rolling. We are at a juncture in history where the decisions we make now will determine the future of our people and our planet. Together we have an opportunity to build a better future. We have to pursue development models that implement sustainable, inclusive and just transitions globally, while leaving no one behind. Improve access to digital services and digital public infrastructure and leverage digital transformation opportunities to boost sustainable and inclusive growth may have to dictate the agenda for innovation so that we can promote sustainable, quality, healthy, safe and gainful employment. Innovations for sustainable and inclusive Social Good are essential for addressing the complex challenges facing our world and building a more equitable and environmentally responsible future. This conference provides the opportunity to make a meaningful contribution to a Society 5.0 in the making.

For the 2024 Society 5.0 conference we encouraged contributions from experienced and young researchers and practitioners from industry and look forward to meeting old and new friends in June 2024.

We sincerely thank all organizers, partners, authors, and reviewers without whom this conference would not have been realised.

Technical Information

We received 76 submissions which were sent out for review to our Society 5.0 programme committee. 29 full research papers were selected for the proceedings of the Society 5.0 Conference 2024 which are published in the Springer CCIS volume 2173 (which translates to an acceptance rate of 38%) after a rigorous, single-blind review process. Further 18 submissions were invited for presentation at the conference. These papers are collected in this report and additionally published with separate DOIs on Zenodo https://zenodo.org/communities/society50-conferences/.

The programme committee comprised 59 members from 12 different countries across the world. Each paper was reviewed by three members of the pro-

gramme committee in a rigorous review process. The review was organized using Easychair, avoiding potential conflicts of interest when assigning the reviewers. Criteria such as the following were taken into consideration: Relevance to Society 5.0, Significance, Technical Quality, Scholarship, and Presentation that included quality and clarity of writing.

Thank you to all the authors and programme committee members, and congratulations to the authors whose research was accepted for publication in these proceedings. And a special thanks to Valeriia Afonina for preparing the proceedings reports.

July 4, 2024 — Knut Hinkelmann
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A Concept for Team Development and Optimisation

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Abstract. With the advent of computerisation in the world of work, mutually dependent developments can be seen in modern industrial societies: the enormous increase in productivity goes hand in hand with the increase in task complexity. Simple and repetitive tasks are disappearing more and more from the realm of human activities as a result of automation. Recently, we have seen an acceleration and accentuation of this development logic. Interestingly, with the introduction of artificial intelligence, the importance of human expertise in the areas of creativity, networked and analytical thinking and solving complex problems is increasing. If we want to ensure the future success of our organisations under these conditions, we must not only redefine the relationship with the members of our organisation, but also shape it in a future-oriented, success-oriented and, above all, employee-oriented way. To this end, we are presenting a concept for team development and optimisation.

Keywords: Leadership, Team development, Team optimisation, Team, Employees, Manager, Team Spirit, Team Identity, Strategies, Roles.

1 Introduction

The team development and team optimisation system we present here is the result of many years of scientific and empirical work. The aim of our endeavours was to develop a process that can be carried out autonomously by each manager, i.e. without the support of consultants or workshop leaders, and as cost-effectively as possible with their own team, as this strengthens the mutual bond on the one hand and increases the manager's leadership skills on the other.

The structured process used can be adapted to the situational and personal needs of the teams to be developed. We suggest that the line manager explains to his or her team the intention:

a) to go through a team development process together,

b) that this process is integrated into the normal course of operations (i.e. no additional time is required),

c) and that this process should not only benefit the team, but also all those involved.

This process transparency is essential because it forms the basis of the relationship (to be achieved) between the manager and the team.

In addition to the individual development steps described below, it is important that the line manager has a continuous dialogue with his team and the individual team members in which the vision of the development, the desired goal and the resulting benefits

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for all are discussed. We are guided here by John Kotter's change management concept [1].

Our concept takes account of our conviction that a focus on measures aimed solely at optimising performance falls far short of the mark and cannot produce successful results in the long term. For this reason, the activities we develop always pursue objectives that are both performance-related and focused on social group cohesion as well as individual benefits in equal measure, as this is the only way an optimisation process can function successfully in the long term.

The process consists of modular components that build on each other and can be completed within a time frame of six to 18 months, depending on the functionality or dysfunctionality of the team to be developed. When designing our system, we placed particular emphasis on a hierarchically open application framework, which means that we can speak of a generic concept.

Empirical findings show that our concept produces the best results for teams of between 7 and 12 people.

2 Reasons

Various factors, such as the acceleration of technological progress due to the digitalisation of working and living environments, and in particular the drastic changes brought about by artificial intelligence, the demographic shift in industrialised countries and the resulting shortage of skilled workers, have had an intensifying effect on the development we have observed in recent decades, in which the level of demands and complexity of the tasks that employees have to cope with have increased more and more. As a result, we have to lead in a more participatory way, extend our employees' room for manoeuvre and discretion and hand over more responsibility.

This is reason enough for managers to place work on the team's performance, ability to cooperate and motivation at the centre of their activities and to associate their self-image as successful leaders with these efforts.

3 Team Status Analysis in Advance

Before team development measures can be tackled, it is essential to analyse the current state of the team. We suggest focussing on the aspects that are important for both team cohesion and team performance:

Values - Motivation, Goals, Drivers - Commitment

An emerging finding of strongly differing views on these topics within a team makes it obvious that successful co-operation is very difficult or even impossible. We have developed the «Team Commitment Tool» in order to quickly gain clarity about the team constitution and the specific discrepancies or dysfunctionalities.

One of the criteria for the analysis tool, as for all the other instruments used as part of our team building concept, was that it should be as easy to use as possible, so that

neither expensive consultants nor workshop leaders are needed, but that every manager can use the tool in their own team after just a few minutes and does not need any help with the evaluation.

It begins with each team member taking a position on the following three questions on a sheet of paper:

1. What is important to me in my job? (The issue here are the VALUES that a person has)
2. What motivates me? What goals do I have? (The issue here are the OBJECTIVES, the MOTIVATION and the KEY DRIVERS)
3. What am I committed to? What do I stand up for? (The issue here is the COMMITMENT)

After all team members have answered their questions, the leader collects the sheets and asks the team to gather around a flipchart sheet.

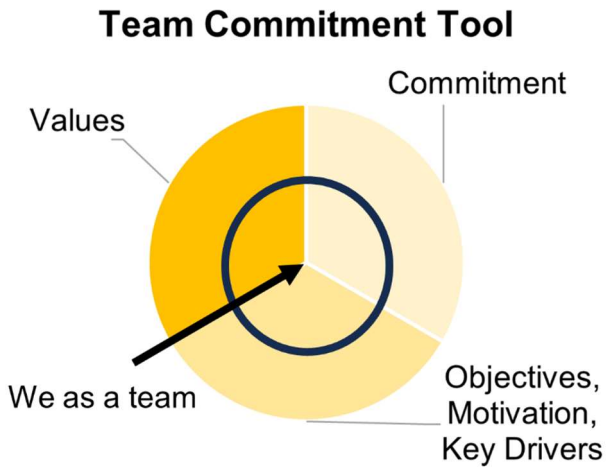

Fig. 1. Inside Team Commitment Tool

There are two concentric circles on this flipchart sheet, the inner one refers to the team's internal perspective, the outer one to the team's behaviour towards various external stakeholders, such as other teams, the company, customers and suppliers. Three equally sized circle segments represent the sphere of values, goals and motivation and the last segment represents commitment.

Now it's back to the same task. The team discusses together what is important to everyone when working together as a team, i.e. the values, what motivates all team members, what common goals the team has as a team and what everyone in the team feels committed to. If there is consensus in the team about the terms that express the common attitude, then these are written into the respective segment. The course of the discussion and how difficult it is for a team to agree on certain terms is in itself an indicator of the common basis of cooperation. For this reason, it is not only important that the supervisor leads the exercise, but also that he or she observes it very attentively, but does not participate in it.

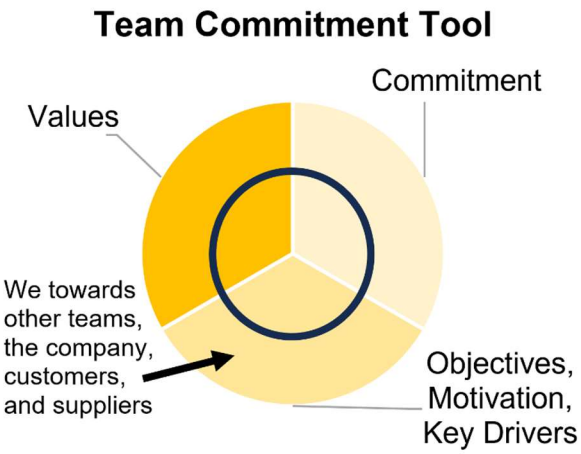

Fig. 2. Outside Team Commitment Tool

In the same way, a consensus is also sought together with regard to the outside world of the team. Here too, the team members agree on what they can agree on when it comes to attitudes towards other teams, the company, customers, and suppliers. Once this exercise has been completed, which should not take more than an hour in total, the leader takes all the individual pieces of paper and the flipchart sheet and records the most important observations as a reminder of the process of this team exercise. The evaluation of the own notes and the recorded statements of the team allow a basic assessment of what needs to be worked on with the team in the coming months. This analysis should be repeated after a few months - the timing is determined by the progress made in the team optimisation process - in order to make the change perceptible.

4 Overview of the system phases

Our concept for team building and optimisation consists of four components that build on each other:

1. Standards and Values
2. Objectives and Strategies
3. Team Spirit
4. Roles and Responsibilities

These are explained in more detail in the following chapters.

Fig. 3. System Phases Pyramid

5 Implementation

5.1 Values and Standards

Once the analysis of the current state of the team has been completed, the process of team optimisation can begin.

Values and standards form the foundation [2]. Every team must be clear about its shared values, its shared convictions, its attitude beliefs, its attitude and therefore its identity. The professional world can learn a lot from sport teams [3] and music orchestras, especially in the area of identity creation, where a great deal of attention is paid to this aspect as one of the prerequisites for success.

General additional remark: Creating a team identity is one of the foundations for team development. It is important to understand that this is not about sectarian conformity or questioning the personal characteristics of team members, but that the whole is more than its parts; each team member wins individually and as a group when team cohesion and team self-image are well developed [4].

Because team identity is a social construct that we can shape at will, the question here is not only: «Who are we?» but also «Who do we want to be?»

The manager should answer the following questions for the current situation (ACTUAL state) of his or her team, after which he or she defines the team TARGET state that he or she is striving for:

- What characterises us? (= Our strengths)
- What makes us special? (= Our uniqueness)
- What is our identity? (= Who are we?)

This preparatory work is important in order to have an idea of where the team identity development should be heading for the guided exercise with the team. If there are

serious differences between the team's answers to these questions and the manager's ideas, detailed individual discussions should take place to find out why the ideas differ so much.

By developing the team identity together with the line manager, the members create a "we" philosophy.

In a second step, the team addresses the following questions:

- What is important to us?
- What do we value?

In this way, the team clarifies what everyone must adhere to, what the team stands for and what the rules are that apply to everyone. In other words: the values, the convictions and the attitude. This is where alignment is created, the common ground that binds a team together. Together with the team, the leader lays down these rules, creating a team constitution that everyone signs. It is also important that the team and the manager determine what the sanctions are if a team member does not adhere to these rules and who should monitor this (this function should be assigned to two team members).

5.2 Objectives and Strategies

Once the team has established a common foundation of standards and the development of a team identity has been initiated (Identity definition in particular is an on-going, never-ending process, because changing team constellations and the rejuvenation of a team also give rise to new ideas and requirements), the common team goals can be defined. Normally the team has a given set of performance targets, but the line manager should not only communicate these at the start of the performance review period, but also discuss them together. The open discussion of predetermined goals in particular also welds a team together. In connection with the discussion of the specified performance targets, a workshop lasting approx. 45 minutes can be held with the team, in which Stephen Covey's «Circle of Influence» [5] is used to determine what the team can and cannot influence. This demarcation helps to allocate resources correctly, increase efficiency and effectiveness and to avoid friction over matters over which the team has no influence. The distinction between «What can we influence?» and «What can we not influence?» is supplemented by the team together with the line manager by defining how they want to deal with this, on the one hand «We are working on this» and on the other hand «We are developing a positive attitude». This also happens, for example, as part of a team meeting as a process of self-understanding.

For the development and optimisation of a team, it is essential that not only performance targets are determined or predefined targets are discussed, but also that social targets are defined for the team and its members. Social goals are at least as important as performance goals because they determine whether a team improves in the long term. Discussing and recording how you want to organise social interaction, that both the modus operandi and the modus vivendi are the subject of discussion, has a beneficial effect on team cohesion.

A social team goal that is defined at the beginning of the performance period can be, for example, the agreement on how to increase team cohesion, the joint development of a culture of error or competence leadership in a specific area of expertise within the

company. However, determining the individual benefits for each team member is also an important topic. This can consist of individual career development, an increase in expertise, an expansion of the scope of action and responsibility or general empowerment. Indicators of the success of these endeavours are typically the falling fluctuation rate or the reduction in sickness-related absences.

Once the team has clarified its goals, the next step is to determine the strategy for achieving them. By jointly clarifying the questions "What is our path to the goal?" and "What are we prepared to do to achieve it?", the team defines the framework conditions for its service provision that are accepted by everyone (e.g. one weekend shift per month for everyone or similar).

This is an open discussion, moderated by the line manager, in which the team makes a voluntary commitment that applies to all members. Precisely because this character of self-commitment must not come about through coercion or manipulation, but must be based on the free and freely expressed will of the team members, it is essential that these discussions take place in an open and transparent manner. Here again, the team consciously works its way to a higher level of identification with its own work and at the same time defines the price they are willing to pay for it.

5.3 Team Spirits

Strengthening cohesion promotes the positive development of a team immensely. To strengthen team cohesion, we suggest a simple workshop exercise that can be carried out in a normal team meeting of 45 minutes. The supervisor needs two flipchart sheets for this. One sheet says «What do I want more of in our team» and the other flipchart sheet says: «What do I want less of in our team». Each team member now writes on the flipchart sheets what he or she would like to experience more or less of in the joint work.

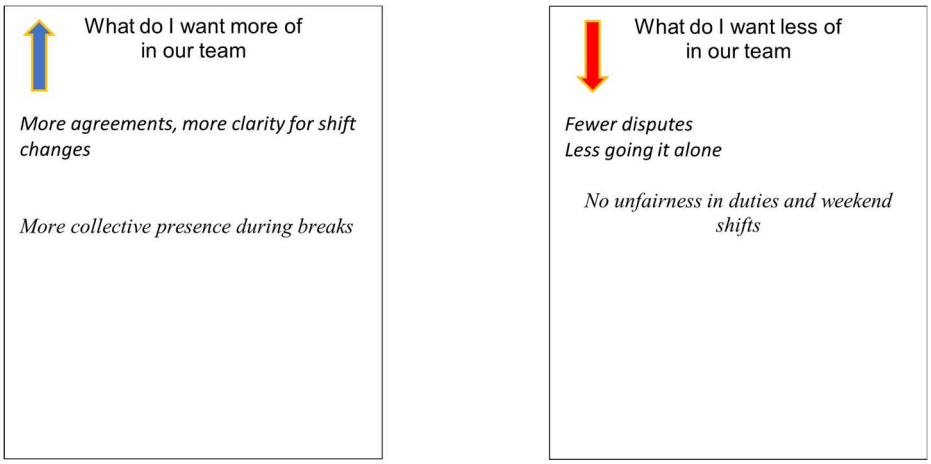

Fig. 4. Workshop exercise “Team Cohesion”

This is a way of expressing individual discomfort or specific concerns and sending a message to the other team members. In this way, the group finds out quickly and easily where the shoe pinches and this can be discussed together and solutions can also be agreed quickly and easily. This exercise of feeling the pulse should be repeated every six months so that a team can rely on this opportunity to make a statement on the one hand, and on the other hand so that unsaid things do not pile up, but can be dealt with quickly before everyone else and with everyone else.

Team cohesion must be achieved by the whole team, even if it is usually the case that the positive alpha persons take the lead in the matter and, for example, organise events and pull the others along.

The questions that the team should clarify here are:

- How do we give each other positive energy?
- What rituals do we use to strengthen cohesion?

In this area of team cohesion, the manager should consciously take a step back and leave it to others to ensure the right mix of activities and occasions. It doesn't matter whether the manager likes the planned activities or not, the main thing is that the team feels comfortable with them. The same applies to team rituals, be it small gifts for birthdays or celebrating achieved performance targets or project milestones.

It goes without saying that not all team members have the same expectations of group social life, not everyone wants to spend their free time with their work colleagues. This is completely legitimate and must be accepted. However, we would like to point out that even the more introverted team members feel more at home in a cheerful and well-functioning team than in an indifferent and socially cold team.

5.4 Roles and Responsibilities

In order to clarify roles and responsibilities in a team the formal instruments of the job description, the clarification of tasks, competences and responsibilities as well as function diagrams and the like are important. However, as a manager (and as a team member) you should remain aware of two aspects:

1. these are usually static (once defined) provisions, such as the job description, which are only adjusted periodically in rare cases.

2. the formal definition is often not binding or clarifying enough on a day-to-day basis to have a positive influence on commitment and engagement.

In joint discussions - e.g. in an assessment of the current situation or in a goal-setting meeting - the manager discusses the following points with their employee:

- What do I have to do? (mandatory)
- What am I allowed to do? (degree of individuality)
- What should I do? (personal expectation)
- What can I do? (self-assessment)

This joint definition of the role and responsibilities of each employee in the team not only defines the content, but also provides both sides with information about mutual expectations [6], the ideas they have about each other, the room for manoeuvre that the employee has (and is granted) and what competences and potential the employee believes he or she has.

It is important that this information is accessible to all team members, because everyone should see themselves as part of the whole, but they should also know from each other what roles the other members have in the collaboration.

6 Conclusion

Every team development process is a never-ending process to improve the individual and the group. The diverse constellation of a team is changed by every departure and every new addition, and the leader must observe these changes and analyse their effects on the structure. Although changes in composition have an impact on every team, teams stabilised through development measures are more resilient to disruptions or challenges.

This newfound resilience and robustness, as well as the increased trust, stronger identification and strengthened motivation, is an added value that comes from working on and with the team.

An optimisation process benefits everyone (the team, the individual members, the leader), but also requires more attention, commitment and work.

This price is easily outweighed by the disappointments, friction and annoyance that everyone has in a dysfunctional team.

Our system aims to optimise performance and team atmosphere for the benefit of all. We are convinced that the simple handling of the process steps offers an opportunity for as many managers worldwide as possible to dedicate their commitment to this goal.

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3. Jonathan Foster's article «Arsenal, Identity, and Evolution» on this topic is well worth reading at https://www.footballparadise.com/arsenal-identity-and-evolution, last accessed 2024/03/14. The German serial football champions FC Bayern Munich may also serve as an example here. Their motto «Mia san mia» (We are who we are) reflects the self-confidence and self-image they have developed over decades, in other words, the identity they have created.
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Adopting Agile in Cybersecurity

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Abstract. The study underscores the growing applicability of agile principles beyond traditional software development, noting their relevance in diverse projects and industries. It suggests that cybersecurity management stands to benefit from agile methodologies due to their adaptability to evolving threats and internal challenges. As a result of this research, the 'M&RA Model' was developed as a readiness assessment tool for the adoption of agile in cybersecurity. The model comprises two steps - assessing cybersecurity maturity ('MA Model') and readiness for agile ('RA Model'). It was developed by analyzing established frameworks and guidelines for both agile and cybersecurity. Through iterative evaluation and refinement, informed by qualitative input from subject matter experts obtained via brainstorming sessions and semi-structured interviews, the model evolved to enhance cybersecurity practices within agile principles and methodologies. This approach aligns with design science methodology, ensuring the model's relevance and effectiveness in addressing contemporary cybersecurity challenges.

Keywords: Cybersecurity, Agile, Maturity, Readiness Assessment.

1 Relevance

Cybersecurity programs are crucial for safeguarding against data breaches and minimizing among others financial and reputational damage [1] (Donaldson et al., 2018). According to [2] WEF (2024), the global cost of cybercrime will rise (forecast) to $23.84 trillion by 2027, highlighting the urgency for efficient cyber defense strategies and related programs within organizations[1].

Cybersecurity related standards and frameworks provide valuable guidance to govern and manage cybersecurity but often rely on traditional project management methodologies [3] [4]. Traditional, mainly linear project and process management in cybersecurity hinder adaptability and flexibility, driving the need for more agile approaches [5] [6]. Agile principles and methodologies offer here a solution to cybersecurity challenges by emphasizing iterative, collaborative, and adaptive approaches [7] [8]. However, before adopting agile principles and methodologies, it's vital to assess an organization's readiness, considering the current cybersecurity program and familiarity with

[1] We used the term organizations as an umbrella term for profit and non-profit organizations, enterprises, companies, authorities, or other forms of organization.

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agile. Such an assessment ensures understanding among leaders, teams, and employees, as transitioning from traditional and well-known approaches to agile can be challenging [9] and cause risks [10] [11].

Agile methodologies prioritize adaptability through continuous feedback and incremental delivery, both crucial for responding to global changes efficiently [12] [13] they streamline processes, focusing on valuable outcomes, especially beneficial in cybersecurity [13]. A previously conducted literature analysis revealed that agile readiness has hardly been discussed at all in the literature and assessments for the adoption of agile methodologies in cybersecurity remain underexplored. Addressing this gap, our research aimed to develop a model to assess the readiness within organizations for agile cybersecurity management. We evaluated both – agile and cybersecurity (challenges) and assessed and selected appropriate standards or frameworks to guide the model's development. Based on literature the following research questions (RQs) were derived:

RQ 1 What agile methodologies suit cybersecurity?

RQ 2 What cybersecurity frameworks aid cybersecurity programs?

RQ 3 How to evaluate cybersecurity readiness for agile adoption?

2 Literature Review

The data collection, as part of the awareness phase, we addressed the subject of adopting agile in cybersecurity to get a solid understanding of the concepts and associated reference models or frameworks. The literature review was mainly based on an extensive and systematic literature review in which we analyzed multiple databases, including Google Scholar, Scopus, IEEE, ScienceDirect, and Taylor & Francis, as well as publications from cybersecurity related associations like CIS, ENISA, ISACA and NIST. The approach for the review was adapted from [14] by analyzing, synthesizing, and summarizing the relevant sources based on keywords including backward and forward queries, iterations and inclusion and exclusion criteria.

2.1 Agile

The term ‘agility’ denotes an organizational structure that is customer-centric and flexible [15]. An agility-promoting culture enables operational adaptability, fosters organizational flexibility and speed; factors that are essential for achieving strategic goals [16]. To achieve agility and self-organization guided by agile principles and team objectives is fundamental [17]. The agile manifesto [19], initially for software development released was influenced by various agile methodologies such as Cristal, Extreme Programming, Scrum or Test-driven Development and has evolved and expanded to diverse domains [18] [13] [6]. However, the methodologies and frameworks remain rooted in the values and principles of the agile manifesto [19]. So far, the most popular has been Scrum, a methodology of managing software projects and developing products with prescribed roles and practices. Agile methodologies and in particular Scrum are ideal for dynamic projects and activities requiring close team-stakeholder collaboration [20]. Table 1 contrasts agile and traditional methodologies, outlines the different

foci of both approaches and shows that agile methodologies excel in complex, fast-changing environments, promoting iterative problem-solving and collaboration.

Table 1. Agile vs traditional project management adopted from Nerur et al. (2005).

	Traditional Methodologies	**Agile Methodologies**
Project Approach	Process oriented	People oriented
Project Flow	Sequential	Iterative
Project Management Style	Command and control	Leadership and collaboration
Team Role	Individual team members' skills	Self-organized teams
Communication	Formal	Informal
Client Role	Important	Critical
Process Model	Traditional project management methodologies like Waterfall.	Agile project management methodologies such as Scrum
Project Lifecycle	Based on tasks or activities	Based on product features

Various agile-oriented frameworks build upon Scrum to extend its applicability beyond the team level [21]. Scrum is a versatile project management methodology applicable across various disciplines [12]. Projects are divided into sprints, each delivering a specific requirement within a defined period, contributing to the overall project goal [13]. According to [9], agile principles are increasingly adopted organization-wide, with Scrum being the most utilized methodology (87%), followed by SAFe (53%). The latter as scaled agile framework is widespread applied because its maturity, and suitability is high, and it is broadly accepted in large organizations [23]. Agile-oriented frameworks frequently use SAFe; one reason is its high maturity. But even Scrum of Scrums (SoS), Large-Scale Scrum (LeSS), or Disciplined Agile Delivery (DAD) are often used to scale Scrum. Table 2 shows a comparison of major agile frameworks organized according to criteria based on [22] and [9].

Table 2. Major agile frameworks compared.

	SAFe	**SoS**	**LeSS**	**DAD**
Team Size	50-120 people in agile release train 5-10 people/team	5-10 teams	10 Scrum teams	200 people or more
Differentiator	Many adaptable artifacts, roles, and guidelines.	Enables scrums for all situations and scales	Offers flexible suggestions.	Complex, with coverage of many models
Underlying Methodology	Scrum and other agile principles	Scrum	Scrum	Scrum, Lean
Maturity	High	High	Medium	Low
Complexity	High-Medium	Medium-Low	Medium-Low	Medium-Low
Global teams	Feasible	Feasible	Feasible	Difficult
Popularity	53 %	28 %	6 %	3 %

2.2 Cybersecurity

Cybersecurity as a term evolved from computer security in the late 20th century to address the changing threat landscape [24]. Initially focused on virus protection [25]

cybersecurity now encompasses a holistic approach to govern and manage technological, organizational, and human aspects of cybersecurity [26]. Main goal of cybersecurity is to safeguard IT assets and digital data against cyberthreats [1], supported by various reference models and standards provided by globally or nationally active organizations like (in alphabetical order) CIS, HITRUST, ISACA, ISO/IEC, NIST.

Creating an effective cybersecurity program poses significant challenges. Many organizations worldwide have selected and combined reference models and standards to support systematic program implementation, operation maintenance and monitoring of cybersecurity [3] [27] [28]. These reference models and standards facilitate primarily cybersecurity architecture (areas like system administration, network security, incident response), policies (defined rules for certain areas), programmatic elements (linkage of people, budget, and technology), IT life cycles (aligns cybersecurity with business strategy), and assessments (evaluate periodically program effectiveness) [1].

3 Research Design

Elaborated from various preliminary discussions with subject matter experts we knew that the successful adoption of agile in cybersecurity - as pre-condition - needs an assessment of (1) whether the organization's maturity level with regard to its cybersecurity program is sufficient and (2) whether an organization is ready and able to deal with the transition from traditional to agile management in cybersecurity. So, the idea was born to develop and evaluate such a maturity assessment as an artifact based on known reference models from both worlds - agile and cybersecurity.

To ensure a systematic approach and achieve rigor we selected ´Design Science Research´ (DSR) as guiding research design. DSR aims to develop and evaluate an artifact based on business needs in a certain environment by using an existing knowledge base which provides the foundations and methodologies from prior research, ensuring rigorous development whereas the environment defines specific business needs, both guide a thoroughness and traceable artifact development and evaluation [29].

4 Model Development

4.1 Methodology

Utilizing DSR, we developed the novel ´M&RA Model´ as an artefact that is suitable as an assessment tool to help organizations decide whether their organization is suitable in principle for the use of agile methods to manage cybersecurity.

The model itself is divided into two separate models – the ´MA Model´ and the ´RA Model´ (both together result in the M&RA model). The MA Model is foreseen to assess the maturity of the cybersecurity program within an organization. If the level of maturity is sufficiently high, it becomes logical to apply the second model – the RA model, to assess the agility maturity within an organization. The RA model can also be performed without the upstream MA model which is offered as pre-assessment (light

approach) but it is recommended only if the organization knows the (sufficient) maturity level of its cybersecurity program (full approach).

We followed DSR using an iterative five-phase process adapted from [30]: (1) '**Awareness**', to investigate and identify the suspected problem and its relevance in more detail, (2) '**Suggestion**', to develop and outline a solution path, (3) '**Development**', to develop a rigor artefact as potential solution, (4) '**Evaluation**', to evaluate the artifact, and (5) '**Conclusion**' to conclude the research and to outline further research recommendations and limitations of the research carried out. The process phases (3) and (4) have been iterated several times, incorporating new information and insights gathered per iteration.

In phase 1, we gathered and analyzed information on agile and cybersecurity to discover the research gap and to derive the RQs. In this phase, the basic aspects of agility and cybersecurity were compiled, and various reference models were compared in order to emphasize the relevance of the problem and gather initial ideas for a potential solution.

In phase 2, we utilized phase 1 results, particularly the analysis of reference models in the field of cybersecurity and agile. We assessed deeply relevant reference models regarding pre-defined criteria (e.g., linked to policy, completeness, useability, conciseness, acceptance, approved by an appropriate authority, collaborative, traceable, applicability across industries, mapping to other standards/frameworks, regularly updated), this resulted after careful comparison and consideration that we decided to use the NIST CSF 2.0 (2023)[2] [31] as foundation to assess the maturity of cybersecurity within organizations - as first step regarding the agile readiness assessment. This phase included understanding how to structure the planned M&RA Model, key elements to consider and based on an enhanced literature review we carried out in this phase we identified and categorized criteria for the model's design.

In phase 3, the M&RA Model was built on information gathered in the previous phases. Expert insights and iterations between phase 3 and phase 4 ensured rigor and solidified the decision to use the NIST CSF 2.0 (2023) [31] as a basis. Table 3 shows core function areas of the guiding framework; these functions were aligned with ´assessment statements´ also derived from the selected framework. Exemplary details for the ´GOVERN´ function area and derived assessment statements are shown in Table 4.

Table 3. NIST CSF 2.0 (2023) – Core functions.

Functions	Description
Govern (GV)	Establish and monitor the organization's cybersecurity risk management strategy, expectations, and policy.
Identify (ID)	Help determine the current cybersecurity risk to the organization.
Protect (PR)	Use safeguards to prevent or reduce cybersecurity risk.
Detect (DE)	Find and analyze possible cybersecurity attacks and compromises.
Response (RS)	Act regarding a detected cybersecurity incident.

[2] We worked with the NIST CSF 2.0 (2023) in its draft version, due to be released in the final version in February 2024.

Recover (RC)	Restore assets and operations that were impacted by a cybersecurity incident.

Table 4. Excerpt: MA Model assessment statements adopted from NIST CSF 2.0 (2023).

Sub-Categories	ID	Assessment Statement (shortened)
GOVERN (GV)		
Organizational Context Mission, stakeholder expectations, legal, regulatory, and contractual requirements are understood	GV.OC-1	Mission guides cybersecurity risk management.
	GV.OC-2	Internal and external stakeholders' needs understood.
	GV.OC-3	Legal, regulatory, and contractual requirements managed.
	GV.OC-4	Critical objectives, capabilities, and services communicated.
	GV.OC-5	Outcomes, capabilities, and services determined

To develop our artifact, we relied on advice from literature about how to develop maturity models. Based on Lasrado et. al (2015), three metamodels for developing a maturity model were derived as foundation: the (1) 6-phase approach for developing metamodels [32], (2) the 8-steps approach for developing metamodels [33]; and (3) the 5-steps approach for developing stage of growth for metamodels [34]. By combining relevant elements from the three metamodels, we could adopt them to develop the M&RA Model. Figure 1 visualizes the development phases adopted derived from [32] [33] [34]. Phase 5 and 6 (grey marked) were not utilized as part of this research, as we focused on the blue-marked phases with its iterative development cycle.

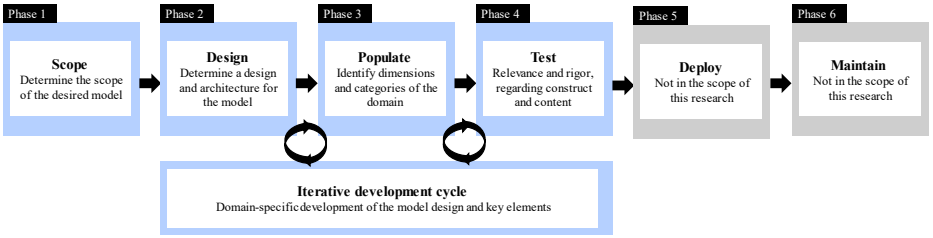

Fig. 1. Development phases for the M&RA Model.

In phase 4, the M&RA Model was assessed and evaluated with cybersecurity and agile experts to determine its validity, reliability, and generalizability.

In phase 5, a summary was drawn up, limitations were documented, and advice given on further research.

4.2 Final M&RA Model (Excerpts)

The M&RA Model is in its final version an Excel-based artefact which provides a comprehensive structure and functionality to assess and visualize an organization's maturity level regarding cybersecurity (MA Model) and agile readiness for cybersecurity (RA Model). Both sub models can also be carried out independently of each other. The M&RA Model is structured using consecutive Excel sheets as guiding path (Figure 2).

Fig. 2. Guided steps through the M&RA Model.

The first sheet ´M&RA Model Introduction´ gives an overview of the model´s structure, including an introduction into the artefact, how and when it can be applied and explains the two different Models (MA Model and RA Model) and its differences and application case with the help of a process flow and a descriptive explanation (below). The next sheet ´Step 1 -->´ leads to the ´**MA Model**´ followed by ´Step 2 -->´ and then going to the ´**RA Model**´. The artefact with its two models can be applied as ´Full Approach´ or ´Light Approach´ (Figure 3).

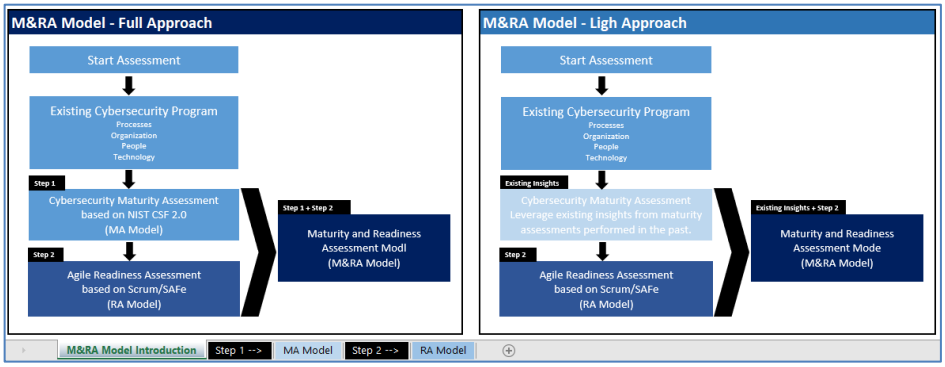

Fig. 3. Excerpt: ´M&RA Model Introduction´ with two selectable approaches.

The ´Full´ approach (Step 1 --> MA Model --> Step 2 --> RA Model) assesses first the maturity of the existing cybersecurity program supported by the MA Model; it can be evaluated which parts (dimensions) of the cybersecurity program have the potential for agile at a scale adoption due to sufficient maturity. Figure 4 shows an excerpt from the MA Model – the cybersecurity maturity assessment with the assessment statements that need to be evaluated. Based on the MA Model assessment results, the following Step 2 - the agile readiness assessment (based on the RA Model) can be carried out.

Cybersecurity Dimensions	Cybersecurity Sub-Categories	ID	Assessment Statement	Maturity Score	Weighting	Weighted Maturity Score	Maturity Assessment	Recommendation
Govern Establish and monitor the organization's cybersecurity risk management strategy, expectations, and policy	Organizational Context	GV.OC-1	The enterprise mission is understood and informs cybersecurity risk management.	3	1	3		**Agile Readiness Assessment is recommended --> Step 2**
		GV.OC-2	Internal and external stakeholders are determined, and their needs and expectations regarding cyber risk management understood.	3	1	3		
		GV.OC-3	Legal, regulatory, and contractual requirements including data privacy and civil liberties regarding cybersecurity are understood and managed.	3	1	3		
		GV.OC-4	Critical objectives, capabilities and services provided to internal and external Stakeholders are determined and communicated.	3	1	3		
	Risk Management Strategy	GV.RM-1	Risk management objectives are established and agreed by stakeholders.	3	1	3		
		GV.RM-2	Risk appetite and risk tolerance statements are determined, communicated, and maintained.	3	1	3		
		GV.RM-3	Enterprise risk management processes include cybersecurity risk management activities and outcomes.	3	1	3		
		GV.RM-4	Strategic direction that describes appropriate risk response options is established and communicated.	3	1	3		
		GV.RM-5	Lines of communication across the organization are established for cybersecurity risks, including risks from suppliers and other third parties.	3	1	3		
		GV.RM-6	A standardized method for calculating, documenting, categorizing, and prioritizing cybersecurity risks is established and communicated.	3	1	3		
	Cybersecurity Supply Chain Risk Management	GV.SC-1	A cybersecurity supply chain risk management program, strategy, objectives, policies, andprocesses are established and agreed.	3	1	3		
		GV.SC-2	Cybersecurity roles and responsibilities for suppliers, customers, and partners are established, communicated, and coordinated internally and externally.	3	1	3		
		GV.SC-3	Cybersecurity supply chain risk management is integrated into cybersecurity and enterprise risk management, risk assessment, and improvement processes.	3	1	3		

Fig. 4. Assessment procedure of the MA Model – Basis of the ´Full´ approach.

Figure 5 shows an excerpt from the RA Model – the agile readiness assessment based on Scrum/SAFe with the assessment statements that need to be evaluated and further criteria (e.g., readiness score, weighting, weighted maturity score).

The ´Light´ approach (Step 2 --> RA Model) assesses the readiness for adopting agile in cybersecurity only (Figure 4 shows an excerpt). For this approach, existing insights from maturity assessments performed in the past are leveraged to evaluate which parts (dimensions) of the cybersecurity program have the potential for agile at a scale adoption due to sufficient maturity.

Cybersecurity Dimension							
Agile Dimension and Subcategories	ID	Assessment Statement	Readiness Score	Weighting	Weighted Maturity Score	Readiness Assessment	Recommendation
Cybersecurity Dimension Product and Services	CD.PS-1	Products and services are dynamically changing based on external requirements (e.g. Threat Landscape, Regulatory Requirements).	3	1	3		A traditional approach might be better suited or further enhancement towards agile is recommended.
	CD.PS-2	Products and services are dynamically changing based on internal needs and requirements.	3	1	3		
	CD.PS-3	Products and services require continuous improvement/changes/adjustments in relatively short intervals < 1 year.	3	1	3		
	CD.PS-4	Business operations can be negatively impacted if new or existing products and services are not provided timely.	3	1	3		
	CD.PS-5	The exact deliverables of a new product or service cannot be clearly defined from the beginning, and iterative procedures are beneficial to achieve the final deliverable.	3	1	3		
	CD.PS-6	The factor time in the product and service delivery is crucial; hence, prioritization and scoping are key.	3	1	3	3.0	
	CD.PS-7	Value delivery has priority over strict adherence to planned procedures and specifications when delivering products or services.	3	1	3		
	CD.PS-8	Decisions about products and services can be made quickly "just in time" and are not slowed by formal processes.	3	1	3		
	CD.PS-9	Products and services are not negatively impacted by enforced formalities and adherence to strictly defined approaches.	3	1	3		
	CD.PS-10	Product and services quality is improved when delivering in iteratively meaning in digestible pieces.	3	1	3		
	CD.PS-11	Many risk factors are related to the product and service, which need to be managed.	3	1	3		
Cybersecurity Dimension Team and People	CD.TP-1	Within the cybersecurity team, individuals with hands-on experience and education in agile methodology are available.	3	1	3		A traditional approach might be better suited or further enhancement towards agile is recommended.
	CD.TP-2	Within the cybersecurity team, individuals with knowledge in agile are available.	3	1	3		
	CD.TP-3	Within the cybersecurity team, the competencies are mixed and appropriately distributed, and required specialists for the different cybersecurity topics are available.	3	1	3		
	CD.TP-4	Key resources within the cybersecurity team are continuously available.	3	1	3		
	CD.TP-5	The cybersecurity team is stable, and fluctuations are rare.	3	1	3		

Fig. 5. Assessment procedure of the RA Model – can be carried out as ´Light´ approach.

The approach explained in Figure 3 (right box) offers an efficient initial assessment of agile readiness without the time-consuming assessment of the cybersecurity program's maturity (Full approach, first Step 1 --> MA Model). The ´Step 1´ part is then replaced by ´Existing Insights´ from other assessments or audits. The light approach provides a position statement. Both approaches, ´Full´ and ´Light´ can either identify gaps that require further development for agile readiness or confirm that agile is unsuitable in the selected cybersecurity dimension. An interpretation and weighting of the score is at the customer's discretion and depends on the customer's situation, needs, use case, goals, and strategy related to cybersecurity and the assessed organization.

Both models – the MA Model and the RA Model – outline assessment results as readiness score and levels along with recommendations (Excel-based table) and with visualizing the maturity assessment result. Figure 6 shows an exemplary assessment result from the RA Model (visualized view) – a spider diagram about the overall readiness of a model organization. The assessment within the RA Model results in statements related to organization-wide prerequisites, cybersecurity program requirements, and internal leadership support. The ´Readiness Score´ and ´Weighting´ are filled based on discussions and workshops with relevant teams and leadership, focusing on the chosen cybersecurity dimension. Interpretation and weighting of the score are discretionary. An average score of ≥ 4 across all agile dimensions suggests potential agile adoption, indicating possible benefits based on organization-wide prerequisites, requirements, and leadership support. The score serves as a positioning statement, identifying

gaps for further development or confirming agile unsuitability in the selected cybersecurity dimension. The recommended score simplifies assessment, aiding in identifying current status, gaps, and improvement areas through the M&RA Model.

Fig. 6. Exemplary RA Model assessment result (visualized view).

The evaluated and incrementally improved final artefact can be downloaded from the public SWITCHdrive: https://drive.switch.ch/index.php/s/rtWIQ3tTuEIfFRo.

5 Evaluation

Cybersecurity and agile experts evaluated the M&RA model in autumn 2023. Initially, input from two subject matter experts was gathered through three brainstorming sessions to ensure iterative improvement and practical adherence during artefact development. Subsequently, three semi-structured interviews were conducted with subject matter experts selected based on previously defined criteria. All experts for the evaluation met these four criteria: (1) expertise in cybersecurity and agile, (2) consulting experience, (3) management position and (4) experience over ten years.

As illustrated in Figure 7, introduction meetings with the experts were conducted first - a few days before the interviews were planned to explain the M&RA Model and the evaluation approach. This step ensured that the experts were prepared and could undertake initial considerations before the interview.

Fig. 7. M&RA Model evaluation approach

The sessions and interviews were held to evaluate the M&RA Model's regarding its (1) validity, incl. missing elements or improvement points, (2) reliability, and (3) generalizability to evidence rigor and relevance of the artefact. Within the discussion the completeness, accuracy, applicability, usability, and not at least the achievement of standardized applicability in the cybersecurity environment have been examined and (feasible) improvement elements have been worked out, documented and iterative improvements have been implemented.

Table 5 summarizes key evaluation findings, including areas for improvement. The experts evaluating the model confirmed the validity, reliability, and generalizability of the final M&RA Model in principle. However, the complexity, scope, and time constraints limited addressing certain points, earmarking them for future research.

Table 5. Conclusion of the conducted semi-structured expert interviews.

Evaluation Area	Summary
Validity	Experts affirmed the relevance of domain-specific elements: ´Score´, ´Levels´, ´Dimensions´, ´Sub-Categories´, and ´Statements´. The M&RA Model is robustly designed and encompasses necessary details. Additionally, experts endorsed the use of CSF 2.0 as it's widely recognized, holistic, and covers key cybersecurity aspects.
Reliability	Experts agreed on the M&RA Model design, confirmed the accuracy and consistency, and that the goal of assessing readiness for agile in cybersecurity is achieved. Experts agreed on the M&RA Model content and structure and calculation approach.
Generalisability	Experts agreed on the M&RA Model's applicability in the cybersecurity environment and confirmed that utilizing CSF 2.0 is appropriate and ensures a standardization model. The experts mentioned that they are interested in seeing the application of the M&RA Model in real-world scenarios.
Missing elements or improvement points (Part of validity)	It's suggested to consider or add, for instance, as starting points for future research: - benchmarking or further guidance for weighting assessment statements. - people, processes, and technology in the agile readiness level. - mapping to other frameworks like ISO/IEC 27001 in the MA Model.

6 Conclusion and Further Research

The novel M&RA Model aids cybersecurity, agile, and implicit organization leadership in achieving agile cybersecurity or benefiting from agile principles. It assesses cybersecurity maturity (MA Model) within an organization to ensure a foundation for agile adoption, then evaluates cybersecurity readiness (RA Model) based on prerequisites, requirements, and leadership support. Utilizing the NIST CSF 2.0 (2023) [31] combined with Scrum and SAFe, the developed M&RA model offers a comprehensive assessment model for the maturity of cybersecurity and agile within organizations. Promising areas for future research outlined in Table 5 and can be summarized as follows: (1) Simplifying the M&RA Model without compromising validity or reliability, achieved through detailed analysis of assessment statements with subject matter experts and surveys; (2) Developing practical guidelines for M&RA Model application, including methodology selection, and addressing common challenges; (3) Quantitatively evaluating the M&RA Model through surveys and expert interviews for further improvement insights.

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Ontology-Based Course Recommendation

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Abstract. This paper addresses the challenge of course selection for students by using the domain knowledge available within course descriptions to improve the decision-making process. The decision-making process for selecting courses is complex, influenced by intrinsic motivations, such as personal interests and academic goals, and extrinsic factors, including career prospects and peer recommendations, shape students' preferences. This paper demonstrates the potential of semantic networks, and ontologies in particular, to match student preferences with available courses. By developing an ontology tailored to the Master's program in Business Information Systems at FHNW University of Applied Sciences and Arts Northwestern Switzerland, we explore the ability of ontologies to refine the precision, relevance, and customization of course recommendations, thereby empowering students to make well-informed decisions.

Keywords: Lifelong learning · Course Selection · Educational Ontology · Ontology-based Recommender System.

1 Introduction

Lifelong learning is a challenge and a necessity for the future of our societies. The inevitability of change in the course of a professional lifetime and the increasing prevalence of technology-related jobs demands for lifelong learning [12]. Acquiring new knowledge and skills cannot be restricted to formal educational settings. People also learn within the context of their work on real-world problems.

Although lifelong learning is more than training or continuing education, formal education is an important aspect as it enables people to gain a deeper understanding of their domain. There are a huge number of study programs and courses in continuing education. A challenge is to select education programs and courses that are adapted to the requirements of professional life, complement learning on the job, and enable participants to develop personally and professionally.

Research highlights several key factors influencing students' elective course decisions, with intrinsic motivations linked to enhanced academic performance, such as a genuine interest in a subject [14]. Conversely, extrinsic motivations

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encompass external incentives like career prospects, evaluation methods, and course timing and location logistical aspects [14].

Consequently, course selection emerges as a recurring dilemma for students every semester, prompting institutions to assist students in navigating this decision-making process to align their course choices with their personal and professional interests and objectives [3]. Even though various approaches were already proposed to support the students in their elective course choice [23], current approaches lack specificity and clarity in offering suitable course recommendations tailored to individual student needs. To bridge the gap between students' preferences and information about the available course options, this paper explores ways of semantically representing course descriptions and leveraging that information to provide appropriate recommendations in line with students' motivations. To obtain high-quality and personalized recommendations, this is approached using semantic networks [13], such as ontologies representing domain knowledge in a processable form [25].

This paper is organized as follows: Section 2 introduces the related work, and Section 3 describes the methodology followed. Section 4 introduces the case of the course section at FHNW. Then, the artifact is described in Section 5. The evaluation is presented in Section 6.

2 Related Work

Domain knowledge refers to expertise or understanding within a specific subject area [21]. Representing this knowledge in a representation formalism, enables reasoning mechanisms to derive new insights from existing information [13]. A benefit of such a knowledge-based system is its ability to support decision-makers with prediction or recommendation features [9]. Semantic networks [13] represent knowledge in a graph structure, where the nodes depict classes or individual entities, and the arrows represent the connections between them. Ontologies are formal representations of semantic networks. Besides top-level ontologies, which capture general concepts across many domains and applications, domain ontologies represent the knowledge within a specified domain of interest [13]. For instance, educational ontologies have the potential to support the course selection of students by increasing the precision of knowledge retrieval by considering the semantic information in the knowledge base.

2.1 Educational Ontologies

In education, the application of ontologies has been recognized for its potential to support students in making informed decisions by offering tailored suggestions for electives or degree programs. Hubert et al. [17] introduce EducOnto, an ontology designed to map university curricula and student profiles with data specific to high school education, aiming to facilitate a smoother transition to higher education and assist students in selecting their field of study. Similarly, Ibrahim

et al. [18] propose an ontology-based personalized recommendation system comprising three distinct ontologies for course, student, and job profiles. This system is intended to improve recommendation quality by aligning study program selections with students' career goals and personal characteristics. However, these methodologies primarily recommend entire study programs rather than individual courses, and both emphasize the representation of course information, such as syllabi.

Chung and Kim [8] argue that if syllabi could be structured in a machine-readable format, it would significantly enhance the educational experience for both students and teachers by providing intelligent services. An ontological model of the syllabus could, for instance, assist teachers in tracking student achievements and performance while enabling students to access more customized learning materials aligned with their objectives and motivations [28]. In this vein, Katis et al. [19] developed an educational ontology encompassing various educational components, including organizations, students, courses, fields of study, and lecturers. This ontology aims to support curriculum management improvements and facilitate syllabus-related activities. As their ontology already represents many important aspects with regard to course selection, it was used as inspiration for the creation of the ontology in this paper. Still, it was complemented with the information needed to be able to address the students' preferences.

2.2 Course Description Contents

The European Credit Transfer and Accumulation System (ECTS) User Guide specifies that a course description should include information on the course content, learning outcomes, workload, teaching and assessment methods, and progression rules, e.g., prerequisites [11]. This ensures transparency and reliability in the educational process. As introduced by Biggs [6], the concept of constructive alignment supports this by advocating for a syllabus design that aligns teaching and assessment methods with the intended learning outcomes, placing them at the heart of the educational experience [1]. The course description template proposed by Barros et al. [5] builds on this foundation and integrates competencies and learning objective taxonomies alongside each learning objective, enriching the course design framework. The ETH Competence Framework [22] further categorizes twenty competencies into four domains, emphasizing the importance of not only subject-specific but also method-specific, social, and personal competencies. While subject-specific competencies are at the center of the ETH Competence Framework, it also considers method-specific, social, and personal competencies to become able to deploy the subject-specific competencies in the first place. Next to the competencies, Barros et al. [5] also reference the learning objective taxonomy, including its levels, to provide a structured approach to defining educational goals. Bloom's taxonomy, a seminal framework established by Bloom et al. [7] and later revised by Anderson et al. [2], offers a systematic method for classifying learning objectives. This taxonomy, evolving from Knowledge, Comprehension, Application, Analysis, Synthesis, and Evaluation

to Remember, Understand, Apply, Analyze, Evaluate, and Create, is a tool for enhancing communication, evaluation, and measurement of learning progress.

Current research has emphasized the importance of different components in course descriptions, particularly the learning objectives and the competencies required to achieve them. It has also recognized the value of decision support systems for students' course selection. However, existing ontologies do not sufficiently address the nuanced relationship between course content and students' individual preferences when it comes to integrating the content of course descriptions and mapping them to students' motivations and goals to recommend elective courses. This gap provides an opportunity for the development of an ontology that leverages domain knowledge about courses, particularly in the Information Systems Master's program, to generate personalized course recommendations that are aligned with students' individual preferences and academic goals.

3 Methodology

The Design Science Research (DSR) paradigm, as outlined by Hevner et al. [15], aims to develop artifacts that address human problems, thereby enriching the knowledge base. With the output of this paper being an artifact (ontology) that addresses a human problem (course selection), this paper contributes insightful new inputs to the existing body of knowledge.

To explore and understand the research problem from a practical perspective, primary data was collected to gain awareness of the student's selection preferences. This involved conducting two focus groups to compare criteria identified in academic literature with students' values. Focus group discussions, conducted using a topic guide derived from the literature, facilitated gathering collective insights and provided a nuanced understanding of student preferences [4].

Building on these insights, a questionnaire was developed to quantify the relevance of different selection criteria among a broader student population. The analysis of survey responses, conducted using descriptive statistical methods, validated the significance of these criteria and refined our understanding of student needs. Additionally, two semi-structured interviews were conducted with lecturers from the Master's program Business Information Systems at FHNW. These interviews aimed to capture the lecturers' perspectives on the utility of course descriptions in guiding student choices and to contrast these insights with students' viewpoints.

Furthermore, a content analysis of course descriptions from various institutions was performed to evaluate the alignment between academic literature and practical application. This analysis helped develop a template for future course descriptions for seamless integration into the instantiated ontology. This template serves as a blueprint for structuring course information to facilitate its extraction and integration into the ontology.

The ontology development followed the methodology Ontology Development 101 [24], beginning with the conceptual layer and progressing to the instantiation

with detailed course description content. Applying Semantic Web Rule Language (SWRL) rules and SPARQL queries [16] facilitated inferential reasoning and information retrieval, enabling tailored course recommendations.

The evaluation procedure followed a set of evaluation criteria relevant to assessing the design phase of an ontology and was divided into two parts. Initially, SPARQL queries addressing specific competency questions evaluated expressiveness, consistency, and completeness. Subsequently, a prototype ontology was tested in real-world scenarios involving a former student[3]. A qualitative semi-structured interview further examined the ontology's accuracy, adaptability, clarity, and cognitive adequacy, ensuring its relevance and applicability to the intended audience.

The interview participant was selected intentionally to compare the course recommendations generated by the ontology in a given scenario to the courses the student chose. The purpose of this comparison was to evaluate the effectiveness of the ontology in matching its suggestions to the student's historical preferences and motivations, thereby assessing the accuracy and relevance of the ontology's recommendations.

4 Course Selection at FHNW

Choosing courses involves students considering various factors such as their interests, future career goals, and the modules' characteristics, making the selection process quite detailed and time-consuming [14]. This situation is mirrored at the FHNW University of Applied Sciences and Arts Northwestern Switzerland. The curriculum of the Master of Science in Business Information Systems (MSc BIS) includes four core courses and a diverse array of electives.

In the focus group discussions, the part-time students of the MSc BIS, who were also working in companies, clearly stated that the compatibility of study times with work commitments plays an important role in the decision-making process. Interestingly, participants preferred acquiring new knowledge driven by personal interest over aligning course content with current job requirements, aiming to broaden their skill set for future opportunities. A desire for a balanced assessment approach to distributing academic workload evenly and a general aversion to excessive group projects was also noted, attributed to the logistical challenges and potential for uneven work distribution they entail.

To further explore these insights, a survey was conducted among 373 BIS students, achieving a 10.2% response rate with 38 completed questionnaires. Participants were asked to prioritize selection criteria, echoing the focus group's emphasis on personal interest as the paramount factor, followed by logistical conveniences such as scheduling and assessment methods. Career aspirations were ranked fourth, slightly diverging from the focus group's slight preference for distinguishing between core and elective courses, though both groups acknowledged career goals as a critical consideration. The survey results largely validated the

[3] Link to the OWL ontology: 10.5281/zenodo.11123166

focus group findings, confirming the consistency of student priorities in course selection.

From the students' point of view, the preference patterns shown in Table 1 were derived from the focus group interviews and the survey.

Table 1. Preference Patterns for Course Selection

Preference	Description
1. Personal Interest	Both in gaining new skills or acquiring knowledge in new domains.
2. Schedule	Achieve a good match of the work and study schedule, mainly for part-time students.
3. Assignment and Assessment Methods	Either considering specific preferences for an assignment type (including group vs. individual work) or wanting to attain a good mix of assignments.
4. Career Aspirations	Acquiring competencies and knowledge in fields that are related to job-specific concepts.
5. Workload	Either minimizing the workload or distributing the workload evenly over the whole semester.

5 Development of the Artifact

An artifact structure, shown in Figure 1, was designed to ensure that the ontology provides recommendations that are consistent with the previously identified preferences.

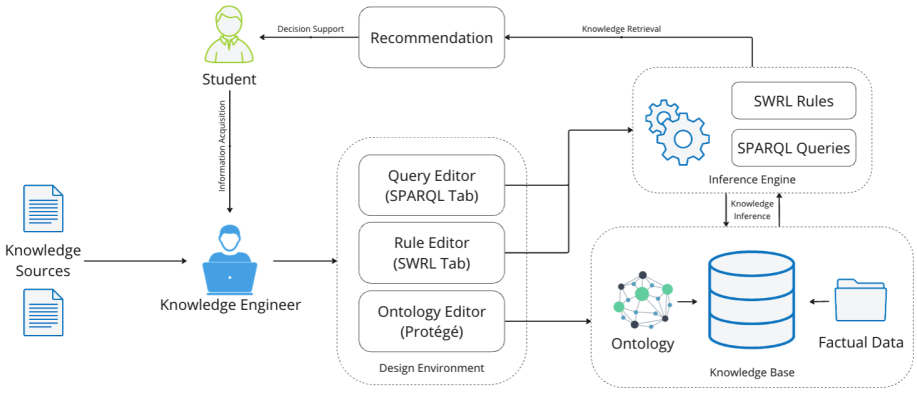

Fig. 1. Artifact Structure

As a pivotal point, the knowledge engineer gathered essential data from student preferences and the course descriptions of available offerings. This step involved mapping and embedding this information into the ontology, a process carried out within the Protégé ontology development environment. This knowledge engineering process expanded the ontology to include main concepts and relationships as well as factual data. This data was used to extend the conceptual framework with real-world examples and establish semantic connections underpinning the ontology's structure. Leveraging these semantic links, the system was equipped to perform inferential reasoning, enabling the generation of tailored recommendations to assist students in their decision-making processes. These recommendations emerged from applying logical rules and SPARQL queries executed on the fully instantiated ontology, with the Pellet reasoner integrated into Protégé facilitating this inference process.

The quality of the ontology and the relevance of its recommendations were further refined through a qualitative evaluation process in which user feedback was taken into account. This feedback loop allowed the knowledge engineers to improve the ontology iteratively, thus improving the quality and accuracy of the recommendations.

5.1 Conceptual Layer

The ontology development started with constructing a conceptual framework that focussed primarily on capturing broad course-related information. To ensure the relevance and applicability of the ontology, a detailed content analysis of course descriptions in the field of business information systems was conducted. The research identified several key components included in course descriptions, including general information (such as course type, semester, and language), an overview of the content, schedule details, assessment methods, instructional strategies, learning objectives, and prerequisites. These elements, along with additional concepts such as student profiles, instructor qualifications, and potential career paths, were combined to form the core classes of the ontology.

A hierarchical taxonomy was employed in structuring these classes, adhering to the guidelines suggested by [24]. This taxonomy was developed using a top-down approach, starting with broad categories like **Course**, **Student**, and **Lecturer** as the foundational classes. Subsequent layers were defined by delineating more specific sub-concepts related to these primary categories. For instance, the **Course** class was further refined to include an **Assignment** class, which itself branched into subclasses such as **Exam**, **Project**, **Report**, and **Presentation**, each representing different types of course assessments.

Additionally, the ontology was enriched with properties that describe the characteristics and relationships of these classes. These properties were divided into object properties, which establish connections between two classes, and data properties, which assign specific attributes or values to a class. Figure 2 illustrates the network of classes interconnected by object properties, visually representing the ontology's structural complexity and the relationships that facilitate its functionality.

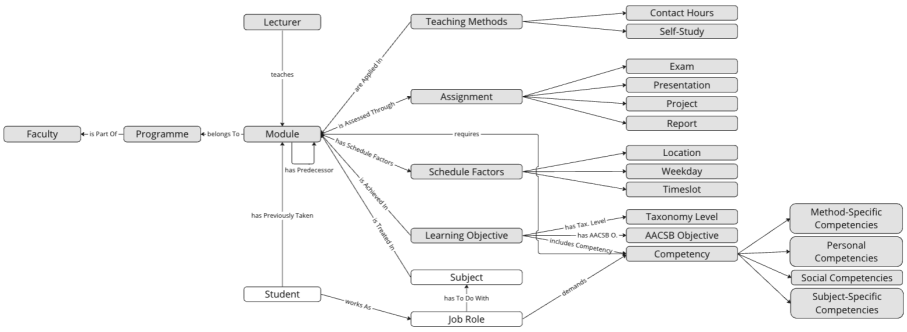

Fig. 2. Classes and Object Properties before Inferential Reasoning

5.2 Instances

The ontology was further enriched with concrete instances. Instances were created for the "Course" class to represent the range of courses offered in the MSc BIS program. These instances included details from the course descriptions, including timetables, lecturers, types of assignments, teaching methods, topics covered, and learning objectives. Recognizing the importance of career choices in course selection, the ontology was extended to include specific job roles relevant to the BIS field. Eight job role instances were added, with the competencies required for these roles being determined based on job advertisements. The class **Competency** is based on the ETH competence framework [22] and comprises its predefined competencies. In addition, the subject-specific competencies, which were taken from the learning objectives and the job advertisements, were divided into thematic areas and integrated as additional competencies. The class **Student** was also of central importance, as the ontology aimed to support students in choosing the study program.

5.3 Inferential Reasoning and Knowledge Retrieval

The final stage involved establishing a mechanism to generate suitable recommendations.

An inference engine is required to interpret and leverage the data and knowledge encoded within the ontology [27]. Inference engines enable the derivation of new instances or relationships from the existing knowledge base. Rule-based reasoning, a form of inference, operates by evaluating whether data satisfies the conditions of predefined rules, thereby augmenting the knowledge base with newly inferred information [26]. For this purpose, rules were articulated using SWRL, enabling the dynamic extension of the ontology's knowledge base.

In parallel, querying plays a crucial role in the semantic knowledge framework, offering a means for users and applications to engage with the ontology. It facilitates the retrieval of information or instances that meet specific criteria.

To bridge the gap between natural language questions and machine-readable instructions, queries must be formulated in a specialized query language. SPARQL is highly recommended for this task due to its robustness and flexibility in handling complex query requirements.

While both SWRL rules and SPARQL queries are instrumental in knowledge retrieval and inference, they serve distinct functions. SWRL rules excel in generating new knowledge from the existing database, enriching the ontology with additional inferred instances [20]. On the other hand, SPARQL queries are particularly effective in extracting specific recommendations, capable of incorporating individual student preferences directly into the queries [16].

Therefore, employing a synergistic approach that combines SWRL rules and SPARQL queries offers the best of both worlds. SWRL rules are utilized to infer new knowledge, enhancing the overall quality of recommendations. Concurrently, SPARQL queries are tailored to fetch precise course recommendations, considering student's preferences.

SWRL Rules: The workload associated with each course was an important criterion for course selection. A statistical survey analysis showed a significant correlation between the number of assignments and the perceived workload. Consequently, specific rules were formulated to categorize workload based on the number of tasks. Therefore, the following rules were constructed: *The workload is high if a course has more than two assignments. If a course has less than three assignments, the workload is moderate.*

A new rule was also established to link courses with competencies, addressing the gap where competencies were previously only directly associated with learning objectives and job roles. The rule says, *if a course has specific learning objectives that include competencies to be achieved, then the course conveys these competencies.* This rule leads to two independent inference chains, where the inferred instances from the class **Competency** are directly reused, and the results from the two following rules build on the outcome of the previous rule. Firstly, *if a course conveys some competencies and a student has previously taken said course, then the student also has acquired these competencies.* Secondly, *if a course treats a specific subject and conveys specific competencies, which are both demanded from or have to do with a job role, then the course is suited for said job role.*

SPARQL Queries: The recommendations were based on the top five preference patterns discussed in Section 4, excluding any courses the student has already completed and including the core courses in any case if they have not been taken yet.

Queries were created for each preference individually and combined into one bigger query to limit the results to only a few recommendations. The final query, illustrated in Figure 3, is structured according to the importance of the preferences, with personal interest being the first priority, followed by career aspirations, schedule preferences, and the preference for no group work. If queried

against the instantiated ontology, only two courses are recommended: On the one hand, “Challenging International Managers and Leaders” as it ticks all the boxes and on the other hand, and “Master Thesis” as it is the only core course the student has not yet accomplished.

```
PREFIX owl: <http://www.w3.org/2002/07/owl#>
PREFIX rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#>
PREFIX rdfs: <http://www.w3.org/2000/01/rdf-schema#>
PREFIX ModuleSelection: <http://www.semanticweb.org/giselebeuchat/ontologies/2023/9/ModuleSelection#>

SELECT DISTINCT ?Module

WHERE{
{ ?Module ModuleSelection:treats ?Subject .
  ?Subject rdf:type ModuleSelection:DigitalBusiness .} UNION
{ ?Module ModuleSelection:treats ?Subject .
  ?Subject rdf:type ModuleSelection:ProjectManagement .} UNION
{?Module ModuleSelection:hasType ?type . FILTER (?type = "Core") .}
{?Module ModuleSelection:isSuitedFor ?JobRole .
  ?Module ModuleSelection:isSuitedFor ModuleSelection:ICTProjectManager .} UNION
{?Module ModuleSelection:hasType ?type . FILTER (?type = "Core") .}
{?Module ModuleSelection:hasScheduleFactors ?weekday . FILTER (?weekday = ModuleSelection:Friday || ?weekday = ModuleSelection:Saturday) .} UNION
{?Module ModuleSelection:hasType ?type . FILTER (?type = "Core") .}
{?Module ModuleSelection:hasGroupWork false .} UNION
{?Module ModuleSelection:hasType ?type . FILTER (?type = "Core") .} MINUS
{ModuleSelection:GisèleBeuchat ModuleSelection:hasPreviouslyTaken ?Module .}}
```

Fig. 3. Combined SPARQL Query Including Different Preferences

6 Evaluation

As specified in Section 3, the focus of the evaluation lay on assessing the design aspect of the ontology as opposed to the implementation aspect. This division stems from [10], who also proposed a set of potentially relevant criteria for assessing an ontology’s design stage. The semantic quality was evaluated with the criteria of expressiveness, completeness, and consistency. Expressiveness relates to the number of competency questions the ontology can answer, and completeness refers to the coverage of the field of interest [10], which goes hand in hand with the competency questions, as they delimit the scope of the ontology. The expressiveness and completeness were fulfilled as answers to all questions were provided within the ontology. Consistency refers to the incapacity of receiving contradicting conclusions from the instantiated ontology [10]. Also, this criterion was assessed by applying SPARQL queries and was fulfilled, as no contradiction occurred.

The second phase of the evaluation dealt with usability in the real world. This was done by applying the ontology’s prototype to the preferences of a former BIS student. The prototype was demonstrated in the Protégé design environment’s SPARQL query tab. There, the queries based on the example from Subsection 5.3 were applied in accordance with the student’s preferences. The results were then discussed in terms of their accuracy, adaptability, clarity, and cognitive adequacy. Degbelo [10] defines accuracy as how well the ontology reflects the meaning of the domain it depicts. From the student’s perspective, all relevant real-world concepts were covered in the ontology, which allowed valuable recommendations

to be returned. Adaptability refers to how easily changes were performed [10]. The ontology appeared adaptable to the student as the queries were adapted to the user's wishes. Clarity means that the intended meaning of the terms within the ontology can be communicated effectively [10]. As the recommendation only provides the names of the recommended courses, the output was easy to grasp. According to Degbelo [10], cognitive adequacy relates to matching formal and cognitive semantics. Regarding the recommendations the ontology provided, the student classified them as qualitatively valuable given the mentioned preferences. Overall, a positive attitude towards the prototype was expressed.

7 Conclusion

This paper tackled the issue of improving course selection for part-time students through the creation of a specialized ontology. This ontology generated personalized recommendations that align with student preferences, covering intrinsic and extrinsic motivation. By considering personal and professional criteria, it supports the selection of courses that align with the requirements of professional life and thus supports lifelong learning. Despite its accomplishments, it is important to acknowledge areas for further development, such as refining the ontology and incorporating machine learning for improved recommendation precision. Additionally, extensive field testing is recommended to evaluate its applicability across a wider student base. Ultimately, this work contributes to the fields of educational technology and decision support, offering a foundation for future advancements.

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Green Entrepreneurial Orientation, Green Innovation and Competitive Advantage among Small and Medium Enterprises: The New Entrepreneurial Revolution

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Abstract

There is growing concern about environment. In view of significant socio-economic contribution of SMEs across countries, this sector plays a key role in achieving 'net-zero' carbon emission. Yet, the underlying mechanism of green entrepreneurship is still at its nascent stage and firm posture in the adoption of green concept has not been given ample attention. The study contributes to the wide literature by assessing the effect of green entrepreneurial orientation, the dual nature of green innovation including green radical and green incremental innovation on competitive advantage. The study develops a conceptual framework to assess the relationship among the different variables and competitive advantage in a small economy island, Mauritius. The study uses a structured questionnaire to collect data among SMEs in Mauritius. SPSS was used to conduct descriptive analysis and regression analysis followed by AMOS to conduct structural equation modelling to examine the model. The study found that green entrepreneurial orientation, green incremental innovation directly affects competitive advantage but the direct effect of radical innovation on competitive advantage was not supported. Radical and incremental innovation mediates the relationship of green entrepreneurial orientation on competitive advantage.

Keywords: Green entrepreneurial orientation, green entrepreneurship, green innovation, green innovation, green radical innovation, green incremental innovation, competitive advantage

1 Introduction

During recent decades, the world has witnessed industrial revolution leading to a rise in the standard of living, economic growth, and significant change in technology [60]. On the other side, the planet has experienced severe environmental degradation [59, 26] including greenhouse effect, depletion of ozone layer, environment pollution, release of toxic substance in the atmosphere, heavy carbon emission, natural disasters, [41] deforestation, over use of fossil fuels, and rise in temperature [60, 61]. In this context, institutions have warned that environmental issues have threatened human well-being, and economic growth [48]. Institutions have called upon countries to invest in renewable energy so as to migrate towards sustainable energy that will enable countries to reduce carbon emission significantly [60]. Moreover, enterprises should invest in sustainable food production that will generate healthy future generation and discourage end products related with deforestation [23]. Along the same line, in view of the significant socio-economic contribution of entrepreneurs across countries, small and medium enterprises (SMEs) have not been spared by their contribution regarding environmental challenges. The report [48] stressed on the role of SMEs to realise the policy of 'net zero' in greenhouse effect. This implies that SMEs play a key role to address the environment challenge and to subsequently move towards a green business model. Hence, entrepreneurs should transit towards green products, process, and technology to mitigate the environment challenge.

The growing environmental concern and its relationship with industries and human related activities [18, 48] has given rise to a plethora of literatures on eco-friendly approaches among industrialists. Studies have shown the importance of different variables among corporates that play a key role to overcome the environmental challenge. However, previous literatures have not provided ample attention towards green posture among Small and Medium Enterprises (SMEs), that is, green entrepreneurial orientation (GEO) and green innovation in the concept of green entrepreneurship. The objective of the present research is to fill this void by expanding our knowledge about green entrepreneurial orientation and green innovation on competitive advantage among SMEs. Moreover, the dichotomous nature of green innovation including green radical innovation (Green RINN) and

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green incremental innovation (Green ININN) have rarely been studied. The present research studies the variables in a single model and demonstrates the importance of those variables in reducing environmental impact.

2 Research Background

2.1 Green Entrepreneurial Orientation

Green Entrepreneurial Orientation (GEO) is the firm level posture to integrate green practices at every organisational function aiming to address environmental challenges as posited by [27]. The writers stated that GEO is founded at the interface of Entrepreneurial Orientation and Green Entrepreneurship while earlier [36] stated that GEO is the integration of firm initiative towards green engagement to preserve the environment. [27:2] define GEO as "firm-level proactive strategic inclination to identity and grasp the eco-friendly business opportunity based on the comprehensive consideration of risks and benefits". In the same vein, [24] argued that sustainability oriented entrepreneurs are willing to look for green opportunities and act upon it by integrating green activities in their production, process, technology, and final products [58]. [36] argued that the adoption of green entrepreneurial posture also implies proactive behaviour that is reflected in green ventures. Similarly, [38] showed that exposure to sustainability opportunities lead to sustainable entrepreneurial position. Thus, it implies that GEO is embedded in green entrepreneurship theory and it plays a key role to overcome environment challenges. Despite its importance in green entrepreneurship taxonomy, GEO has not received ample attention in the academic literatures. The present study fills this void by investigating firm level green posture and its effect on competitive advantage among SMEs.

Moreover, few studies on GEO have focussed on the triple bottom line including the dimensions of environment, social, and economy [45,38]. [8] studied the social and innovative posture of GEO. In contrast, [27] argued that GEO should not be looked at solely for the triple bottom line but should also be based on pioneered EO studies by scholars such as [42] and [19]. The latter argued about the multi-dimensions of proactiveness, risk-taking, opportunity seeking, and competitive aggressiveness [62].

[24] argued that sustainability oriented entrepreneurs are willing to look for green opportunities and integrate them in their production process and technology leading to the creation of green products. Similarly, [36] argued that the adoption of green posture also implies proactive behaviour reflected in green ventures whereas [38] demonstrated that exposure to sustainability opportunities lead to sustainable entrepreneurial position at firm level. Thus, the current study posits that green oriented entrepreneurs look for green opportunities and implement them in their daily activities in the form of process, technology or final product to achieve different degree of innovation ranging from incremental to radical innovation. For instance, a green firm will look for opportunities to reduce level of carbon emission or decrease pollution emitted in the atmosphere; while other firms may seize opportunity of the green market by venturing in organic products. Moreover, in line with [63] the present study posits that green oriented firms will undertake risk to invest in green technology, make incremental or radical changes in the process or introduce green products with a chance of high return. Most research has focussed on the behavioural aspects of green entrepreneurial orientation. Few studies demonstrated that GEO influences financial performance [36], environmental performance, [25, 53] or competitive advantage [13, 51]. Again few studies have displayed the combine effect of GEO and green innovation [27,45].

H_1: Green entrepreneurial orientation has direct positive relationship on competitive advantage

2.2 Green Innovation

Previous literature and report have demonstrated that innovation fuels the growth of economy [31, 48]. Another school of thought, claimed that green innovation (GI) is crucial to address the global environment crises to transcend towards a greener economy (60, 61, 2] and create social value [6]. Subsequently, GI has gained ground in the green entrepreneurship literature and research claims that integrating GI in the strategic framework mitigates environment degradation [15, 33, 3]. In this view, scholars and commissions have attempted to define GI as: "innovation that incorporates novelty in the holistic business model, starting from the production process

until disposal that enables an enterprise to migrate towards a greener economy throughout its life cycle" [11:1075,48:3].

This implies all aspects in an organisation should move towards sustainability that includes:

Green production process embodies adoption of technology that reduces carbon emission, emission of toxic substances in the atmosphere, prevents environment pollution, and use more renewable resources in production process.

Product starting from acquisition of bio raw material as input towards the end product that incorporates green attributes until disposal.

Green packaging is packaging that is biodegradable, can be reused or recycled, for example regulation introduced in Mauritius regarding banning of plastic bags to protect the environment led manufacturers to launch environment friendly packaging that are biodegradable.

Though GI has gained importance among firms yet research on the topic is still nascent. Despite few literatures have studied the dimensions of product and process innovation [12, 17, 3] yet the study of bipolar dimensions of green radical and green incremental innovation in the green entrepreneurship literature has rarely been seen [15, 1, 21]. The current study aims to fill the void in the literature by studying the two continuum of green innovation among SMEs.

The current study attempts to define green radical and green incremental innovation from [34:3] and [15: 7789]. The authors defined green RI to 'incorporate revolutionary changes departing from existing products, services, processes to embrace the integration of green concept using green technology that reduces environment degradation and creates value to end customer' and green ININN that involves the 'adjustment, improvement or refinement of existing products, services, processes to embody green features, attributes and knowledge using green technology to reduce environment degradation'. Few scholars have attempted to study green radical and incremental innovation [15, 21, 54]. Few studies demonstrated the effect of green innovation including green product, process innovation on competitive advantage [17, 12, 55], green competitive advantage [16] or organisational performance [10, 33]. Yet, the study of green RINN and green ININN on competitive advantage has rarely been studied [1]. The current study aims to study green radical and incremental innovation in the green entrepreneurship concept and the relationship on competitive advantage.

H_2: Green radical innovation has direct positive relationship on competitive advantage

H_3: Green incremental innovation has direct positive relationship on competitive advantage

2.3 Competitive Advantage

[40] argued that competitive advantage emanates from the resource-based view theory, that is, if firms possess resources that are rare, valuable, inimitable or non-substitutable [4, 5] then the firm gains competitive advantage in the industry. Competitive advantage also depends on the capabilities possessed by firms such as skills, knowledge, marketing capabilities which subsequently generates competitive advantage [37].

In the same vein, [18] argued that previously CA was based on economies of scale or firms offering low price [40] while in the present era, CA is based on value creation or firms offering superior value than competitors. [50] revealed that CA displays two dimensions including cost leadership and differentiation. Whereby, the present study argues that firms adopting an environmental friendly posture generates CA in the market and that GEO, Green radical and incremental innovation provides firms with competitive advantage.

H_4: Green radical innovation mediates the relationship of GEO on competitive advantage

H_5: Green incremental innovation mediates the relationship of GEO on competitive advantage

3 Research Framework

After studying the wide literature on green entrepreneurship, the objective of the current study is to address the theoretical gap in existing literature by studying the relationship between GEO, green radical and incremental innovation on competitive advantage among SMEs. The study further examines a conceptual model incorporating GEO with green RINN and green ININN as mediator on competitive advantage. Though previous literatures have studied GEO in green entrepreneurship, yet the joint relationship of GEO and Green innovation has rarely been studied. Moreover, green innovation including green radical and incremental innovation as a mediator on GEO among small enterprises has not been seen. The current study fills this void and proposes a conceptual framework to assess the joint effect of GEO, GRINN and Green ININN in a single model.

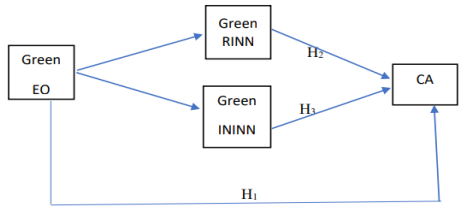

Fig. 1: Conceptual Framework

4 Context of Study

Mauritius is a small economy tropical island located in the Indian Ocean. The estimated population is 1.2 million with a broad ethnic diversity. The economy had undergone different stages of development from primary sector of agriculture particularly sugar to manufacturing during the industrial revolution. Recently, the country has shifted to service-oriented economy mainly the tourism sector, health sector, financial services, information, and computer technology sector [64]. In the same vein, small and medium enterprises (SMEs) represents a significant share of the economy.

Survey conducted by [56] showed that SMEs represent a contribution of 40 percent GDP of the island with 252 400 employees working in the industry and 108 000 unit of SMEs operating. The SME Mauritius defines SME in Mauritius as micro enterprise with an annual turnover not exceeding 10 million; small enterprise with an annual turnover exceeding 10 million but not exceeding 30 million and medium enterprise as turnover exceeding 30 million but not exceeding 100 million.

Moreover, despite the economy has experienced favourable economic transition [57, 64] the island has not been spared by climatic change manifested as vulnerability to rise in sea levels, variations in temperature, extreme weather events, and fluctuations in rainfall [35]. Subsequently, the government has enforced several laws regarding environment protection [43] and the Ministry of Environment has implemented projects to transcend towards a greener economy. SMEs have been integrated in projects to reduce waste, encourage recycling of materials, use green energy, reduce pollution and adopt green technology and green process [44].

5 Methodology and Data Collection

5.1 Measurement and Constructs

The study adopts a quantitative method using a structured questionnaire for data collection. Constructs to assess independent variables and dependent variables were designed after thorough study of the literature review and were adapted from empirical studies. Measurement items in the questionnaire followed Likert scales of 1 to 5 ranging from strongly disagree to strongly agree where 1 represented a weak posture of the variable and 5 represented the strongest posture of the variable. Measurement constructs for independent variables comprises green innovation and green entrepreneurial orientation while dependent variable is competitive advantage. The study identifies two types of innovation namely green radical innovation and green incremental innovation whereby measurement items are derived from the study of [1]. Green radical innovation consisted 5 items and

green incremental innovation consisted 6 items to measure the respective constructs. Green entrepreneurial innovation is new to the literature and therefore there are few reliable scales to measure the construct green EO for the current study. Therefore, items used to measure the construct of EO was designed after studying research from [36] and [45]. The two measures were combined into 6 items to measure EO. The dependent variable, competitive advantage was designed using 6 items based on scales developed by [52].

5.2 Sampling and Data Collection

Data was collected from SMEs in Mauritius operating in different sectors. List of SMEs was taken from the directory of Enterprise Mauritius. The study focussed on manufacturing sectors including Food and Beverage, Leather and Garments, Bioorganic and Medical, Handicraft, furniture and the Agricultural industry. Manufacturing sector is key to carbon emission, pollution and the use of raw material. Subsequently, the transition towards environment friendly activities such as the adoption of green technology, use of renewable resources will enable to transit towards green economy. The Handicraft sector was included because these enterprises use recycling materials in the production process. Sample was selected based on judgement from the list respecting the threshold defined by SME Mauritius and which satisfied the selection criteria for the study. Respondents selected for the questionnaire were employees who were aware about the green concept being implemented in the enterprise and included owner-managers, factory or operation manager, marketing officers, general manager, supervisor and administrative persons. Firms were contacted by telephone to explain the objective of the study and to seek an appointment. 200 firms were contacted by telephone and 50 firms agreed to participate in the study, yielding a response rate of 20 percent. Data collection from SME is challenging and the same can be experienced in Mauritius. Therefore, to increase the response rate convenience sampling strategy was adopted. SME fairs were visited and owner-managers were approached, the purpose of the study was explained and they were requested to fill the questionnaire. Face-to-face survey was adopted in all cases so that clarity can be provided in case the respondent has difficulty to understand the questions. At the end of the study 104 duly filled questionnaires were collected.

6 Results and Findings

6.1 Profile of respondents

Data was collected from SMEs in Mauritius targeting the manufacturing industry, agricultural sector, printing and digital firms. Data was collected for a period of one year and ended with a sample of 104 duly filled questionnaire. The demographic profile of enterprise and respondents is shown in table 1:

Table 1: Profile of Respondents

Sector	Frequency	Percentage (%)
Food & Beverage	26	25
Leather & Garments	23	22.1
Furniture & Wood	15	14.4
Printing & Digital	5	4.8
Handicraft	15	14.4
Agriculture	7	6.7
Bioorganic,Green energy	12	11.6
Plastic & Chemicals	1	1.0
Role of respondent		
Owner-manager	58	55.8
Factors/operation manager	6	5.8
Marketing & admin	23	22.0
management	11	10.6
Interior design	1	1.0
Account/finance	6	5.8
Gender		
Male	59	56.7
female	45	43.3
Highest level of education		
Primary level	5	4.8
Secondary level	40	38.5
Undergraduate/professional	40	38.5
Postgraduate	16	15.4
Vocational	3	2.9

Sales Level		
< 5M	51	49.0
5M – 10 M	21	20.2
>10 M – 20 M	7	6.7
>20 M – 30 M	9	8.7
>30 M – 40 M	2	1.9
>40 – 50 M	8	7.7
>50 M	6	5.8

6.2 Analysis of constructs

The reliability of scales for each constructs were assessed using firstly Cronbach alpha reliability test. using SPSS. Cronbach alpha for GEO displayed value of 0.806. One item from green RINN was deleted 'our firm invest in modern technologies to create new green products' and subsequently reliability test yielded value of 0.771. further, green ININN construct displayed value of 0.806 and 1 item from competitive advantage 'our enterprise is more profitable than competitors' was removed leading to a value of 0.833. All constructs demonstrated an acceptance reliability value above 0.7 [28]. Table below shows the Cronbach alpha values and descriptive analysis values of each construct.

Table 2: Descriptive analysis of constructs

Constructs	Items	Mean	SD	Skewness	Kurtosis	Cronbach
GEO	7	3.8	0.58	-0.59	0.57	0.806
Green RINN	5	3.8	0.54	-0.077	0.048	0.771
Green ININN	6	3.88	0.52	0.099	-0.57	0.806
CA	5	3.81	0.56	0.12	-0.42	0.833

Moreover, linear regression was performed to examine the direct effect of independent variables GEO, green RINN, green ININN on the dependent variable competitive advantage. The direct relationship of GEO on competitive advantage was significant (sig.=0.00) and adjusted R-square was 0.491 thus accounting 49.1% of the model. Further, the direct relationship of incremental innovation was significant (sig. = 0.00) and adjusted R-square of 0.605 or accounting for 60.5% of the model.

6.3 The Measurement Model

Secondly, the current study followed 2 steps process to test the structural model using AMOS. Firstly, the measurement model was tested and confirmatory factor analysis was employed to evaluate the reliability of scales followed by examining the structural model. [46] suggested flexibility regarding cut-off criteria and that for smaller sample size value of comparative fit index (CFI) close to 0.95 should be acceptable while [29] stated that RMSEA between 0.05 and 0.08 shows a fair fit model. Two items from the construct GEO including GEO3 and GEO4 was removed since factor loadings were less than 0.5 while all other items displayed value of more than 0.5 in the measurement model. In the same line the measurement value displayed value of RMSEA 0.07, being less than 0.8 represents a good fit of the model. Comparative fit index (CFI) yielded value 0.9, Tucker Lewis Index (TLI) 0.9, Goodness-of-fit index 0.81, PCFI 0.81 while the measurement model was significant (p-0.00; DF – 183).

6.4 The Structural Model

The second step employed was to assess the structural model. The structural model displayed RMSEA value of 0.07 indicating a fair fit of the model. According to [32] value close to 0.00 shows a good fit of the model while value of 0.05 to 0.08 shows a fair fit of the model. The structural model shows a significant value of 0.00 (DF = 225). Moreover, the model showed Normed fit index value 0.8, Comparative fit index 0.90, Tucker Lewis index 0.90. The model also showed that the direct path green radical innovation on competitive advantage is not significant while all the other paths are significant. Results also showed that H1, that is the direct relationship of GEO on CA is significant (p value-0.00). Hypotheses H_3 which explains the direct effect of GININN on CA is also significant (p value- 0.00) but the hypotheses H_2, the direct effect of RINN on CA is not supported (p value – 0.60). The model showed that GEO is mediated by GININN and GRINN on Competitive advantage and hence

the hypotheses H_4 and H_5 are supported. The study therefore demonstrates that green innovation including different degree is important to adopt an eco-friendly posture.

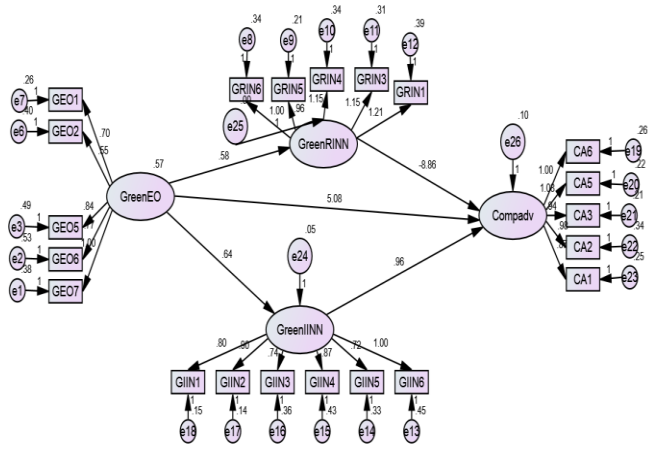

Fig. 2: The Structural Model

7 Discussion and Conclusion

The study was conducted among SMEs in the Mauritian context. A conceptual model was constructed to test the relationship between the independent variables, mediating variables and dependent variables. The constructs green EO, green RINN, green ININN and competitive advantage were integrated in a single model.

The current study revealed that SMEs integrate an innovative posture to transcend towards green practices in their daily operation. Grants and loans offered at low interest rate by banks are opportunities for entrepreneurs to venture in green business. In line with [63], entrepreneurs undertake risk by investing in the development of sustainable product lines and technology to reduce environment degradation. For instance, few entrepreneurs have imported new equipment that enable less energy consumption or reduces carbon emission in the atmosphere. Further, following the ban of plastic bags in Mauritius, entrepreneurs have seized this opportunity to produce and commercialise eco-friendly bags and biodegradable packaging. However, in line with the study of [9], it seems that SMEs do not adopt an aggressive competitive posture and they prefer to work for themselves without paying attention to competitor's activities.

Consistent with [14, 15] the current study revealed that entrepreneurs have integrated the use of environmental friendly raw material in the production process. That is, raw materials used in production process comprises recycled, re-used, biodegradable or bio materials in the production of creative, novel end-products. Further, in line with the [61] recommendation, SMEs have invested in the use of green renewable energy such as photovoltaic cells to migrate towards sustainable enterprise. The use of green energy such as implementation of photovoltaic cells in the daily operation is embedded in the green entrepreneurship concept in Mauritius since the government has provided owner-managers with financial facilities to move towards the use of green energy.

[1, 13] demonstrated that green innovation allows enterprises to differentiate themselves leading to competitive advantage. In contrast, the current study showed that the hypothesis H_2 is not supported and that the direct effect of radical innovation on competitive advantage is not significant. This may be explained by the fact that there is lack of awareness about environment challenges among Mauritian population or else the existence of completely new green products, process or technology are unknown to final customers. In contrast, the hypothesis H_3 is supported showing that green incremental innovation has a positive relationship on competitive advantage. It could be seen that SMEs have done minor changes, adjustment or improvement in the

product, packaging, process or technology to make the existing concept green and reduce pollution. It was also seen that incremental changes in process, technology or product lead to competitive advantage. Moreover, to comply with government regulations, entrepreneurs have implemented minor improvement in the packaging of products to make it biodegradable. Few entrepreneurs claimed the implementation of R concept in the routine activity including Recycle, Reduce, and Re-manufacture in the production process.

8 Managerial and Policy Implication

The findings of the current study provide important insights to implement sustainable practices among SMEs. In line with [7], the study reveals that government and institutions should reinforce policies to orient towards a sustainable society.

The current research found that it is imperative for the government to provide support to SMEs for the effective implementation of eco-friendly activities. For instance, the Ministry of Environment is working with entrepreneurs from medium enterprises to implement sustainability project and promote the use of green energy. It is recommended that the project be extended on a larger scale and among smaller counterparts. Moreover, financial assistance, including grants and low interest loans, are essential to re-engineer enterprises towards green technology, green process, and the development of completely new green products.

Green entrepreneurial orientation and green innovation allows firms to reduce cost and create superior value to customers, leading to competitive advantage. The study recommends entrepreneurs to integrate sustainable development in their operation. Incumbents should innovate to migrate towards the adoption of green technology to decrease pollution. The study revealed that recycling and re-use enables the society to cut down on waste for example textile and handicraft enterprises use remaining of raw materials in the production process to commercialise creative products.

Additionally, it is recommended to conduct awareness campaign among the general population to enhance the use of green products. Owner-managers should comply to policies and incumbents should be willing to re-engineer the enterprise towards environmental friendly tasks and activities.

9 Limitation of Study and Further Research

The current study has some limitations. For instance, the study follows quantitative cross-sectional method among 104 small and medium enterprises. The study can be extended to a greater number of firms to get more insights. The study can also be complemented by qualitative study including focus group to generate more findings and ideas about actions that can be taken by the government and institutions to motivate entrepreneurs transcend towards environmental friendly activities.

Abbreviations: GI-Green innovation, green RINN – green radical innovation, Green ININN-green incremental innovation, CA- competitive advantage

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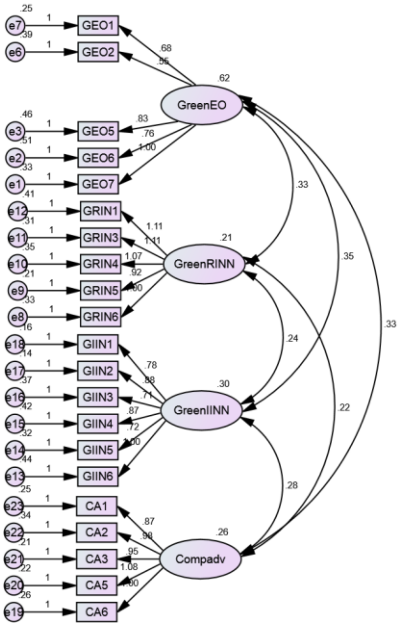
Table 3: Measures for constructs

Green Entrepreneurial Orientation (Jiang et al., 2018; Muangmee, et al., 2021)	
GEO1	In general, our firm favours a strong emphasis on green practices, such as R & D, technological leadership, and innovation
GEO2	When facing uncertainty, we typically adopt a proactive posture in order to catch potential green opportunities.
GEO3	"In dealing with competitors, we typically initiate green actions that competitors do."
GEO4	"In dealing with competitors, we typically adopt a competitive 'undo-the-competitors' posture."
GEO5	Our organization uses less or non-polluting/toxic materials.
GEO6	Our organization has a strong tendency for high risk green product development projects which have a chance of high returns.
GEO7	"Our organization has a tendency to be a market leader, always first in introducing green products, services, or technologies"
Green Innovation	
Green radical innovation (GRINN) - Al-Khatib, A. (2022)	
RINN1	"Our firm invents a new generation of green innovations in its products and services."
RINN2	Our firm invest in modern technologies to create new green products.
RINN3	"Our firm is making new radical organizational changes that reflect its orientation towards innovations."
RINN4	"Our firm is interested in introducing new experiences that did not exist before in terms of green technology."
RINN5	Our firm focuses on new environmental ideas.
RINN6	Our firm creates new green distribution channels.
Green incremental innovation (GIINN)	
GIINN1	Our firm is working on minor changes to existing green products and services.
GIINN2	Our firm is constantly making improvements to its green operations.
GIINN3	"Our firm encourages employees to generate new ideas supporting its green innovations."
GIINN4	"Our firm encourages staff to hold regular meetings to listen to the best ways to make improvements to existing green products."
GIINN5	"Our firm periodically improves and maintains production lines to reduce waste and pollution risks."
GIINN6	Our firm has effective and efficient waste recycling systems.
Competitive advantage (Qiu et al., 2018)	

CA1	The quality of products or services offered by our enterprise is of better/higher quality than that of competitors.
CA2	The enterprise is more capable of R & D than competitors.
CA3	The enterprise has better managerial capability than competitors.
CA4	Our enterprise is more profitable than competitors.
CA5	Our enterprise has a better corporate image than our competitors.
CA6	The competitive advantage of our enterprise is difficult to replace by competitors.

Fig. 2: Measurement Model



Data Traceability for Lifecycle Management

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Abstract.
Purpose – This paper studies the benefits of applying a single lifecycle management approach to improve data traceability. Through digitalization there is an increasing rise of "smarter" products. Hardware and software of **smart products** need to be managed throughout the entire product life cycle, requiring product traceability from product and application lifecycles.
Design/methodology/approach – The Design Science Research approach was applied. Data was collected at a Swiss company with around 16'000 employees worldwide via qualitative interviews (n=10) in an IT integration project with dispersed teams worldwide. The identified requirements were tested in an artefact with business using the tool Polarion.
Findings – The main result of this research shows that **product data traceability** can be improved with one life-cycle management tool, which increases efficiency and improves the transparency of processes and disciplines. Findings from interviews confirmed the following requirements: direction, consistency, effort, completeness, visibility, and clarity.
Business implication – Smart Products are of raising importance for producing companies. However, traditionally ALM (software) and PLM (product/hardware) tools exist with different users and purpose. The study suggests the implementation of an integrated smart product life-cycle management tool due to its identified benefits to **increase efficiency** through training of users as well through **harmonization** and **standardization**.
Originality/ Value – The study revealed various perspectives of senior manager and application manager on lifecycle management. Different levels of management in the company, as well as their skills, have different opinions on data traceability and data integration benefits.
Type of work – Empirical Paper

Keywords: – Data Traceability, Digitalization of Products, Lifecycle Management, System Integration

1 Introduction

Through digitalization there is an increasing rise of smart products. **Smart Products** are of raising importance for producing companies. Under smart products we understand hardware, software, and the communication with its environment. Hardware and software need to be managed throughout the entire product life cycle requiring product traceability.

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DOI: 10.5281/zenodo.12091105

Smart products have three core elements, **physical**, **smart**, and **connectivity** 1. These increase each other's values in loops 2. Smart products' production increase demand to maintain the lifecycle of the product differently than the non-smart product's product lifecycle management. Smart product lifecycle management tool contains a lot of data about the product, which are used increasingly in the strategic decision making of the company.

Table 1 lists abbreviations, definitions, and their respective technology.

Table 1. List of abbreviations and respective technology (own).

Abbreviation	Definition	Technology
ALM	Application Lifecycle Management	Software
HM	Hardware	Hardware
PLM	Product Lifecycle Management	Hardware / Product
SM	Software	Software

By digitalization of business processes product data traceability is of rising importance. Traceability is supported by PLM/ALM tools. To have a digital platform which contains the complete data of a product and data governance, PLM and ALM integration is necessary to be implemented in the product development environment.
This paper is the result of a one-year research process on product digitalization platforms to answer the question how system integration can be applied to integrate ALM and PLM Lifecycle Management Tools.

2 Literature Review

A literature review was conducted on product digitalization platform and traceability with forward and backward searches. Searched keywords include data traceability, ALM, PLM, ALM/PLM integration, product digital representation, smart products, digital transformation, and product development process.

2.1 Key Concepts on Data Traceability and ALM/PLM Integration

A smart product is a highly complex product containing a big amount of data about itself. In today's globalized manufacturing landscape, collecting, managing, retaining, maintaining, and protecting the product's data throughout the life cycle is a substantial challenge for companies 3.
Product Data Traceability includes topics of traceability, product requirement management, change management and test management. As a general term, traceability is applied to many sectors. In the field of product development, it is about tracing the changes in the product requirement management, change management and test management processes.
ALM/PLM Integration/System Integration describes integrating ALM and PLM as an integration of two systems matter, thus system integration is the overarching concept. Table 2 provides an overview of key terms and their definitions.

Table 2. Overview of key terms (own).

Key term	Definition
Product Data Traceability	Product traceability can be distinguished between internal and external traceability. The focus of "**internal traceability** refers to the **record keeping of a product information** within a single production process." 4. The ability to describe and follow the **life of requirement**, in both a **forwards and backwards direction** (from its origins, through its development and specification, to its subsequent deployment and use, and through all periods of on-going **refinement and iteration** in any of these phases 5. Defined from a requirements engineering perspective as the term traceability was first introduced around 1970s in the area of **requirements engineering** in **software development** 5.
Application Lifecycle Management (ALM)	"It indicates the coordination of activities and the management of artefacts (e.g., requirements, source code, test cases) during the **software product's lifecycle**" 6.
Product Lifecycle Management (PLM)	"It is the business activity of managing, in the most effective way, a company's **products** all the way **across their lifecycles**; from the very first idea for a product all the way through until it is retired and disposed of" 7.
ALM/PLM Integration / System Integration	"It is a component of the system engineering process that unifies the product components and the process components into a whole. It ensures that the **hardware, software, and human system** components will **interact** to achieve the system purpose or satisfy the customer's need" 8.

Throughout its life cycle PLM handles the physical product (HW) from the idea generation to the retirement phase in the most effective way 7. From the part of the software, the digital product part (SW), ALM processes and tools manages SW creation process by SW engineers 9.
In many smart product manufacturing organizations, HW is developed by a product development team, and SW development teams develop SW. All the related activities such as requirements collecting, designing, testing, and production are performed separately by separate teams 10.
A framework of product traceability includes several variables, which have been grouped around four pillars of product identification, data to trace, product routing and traceability tools 11, see figure 1.

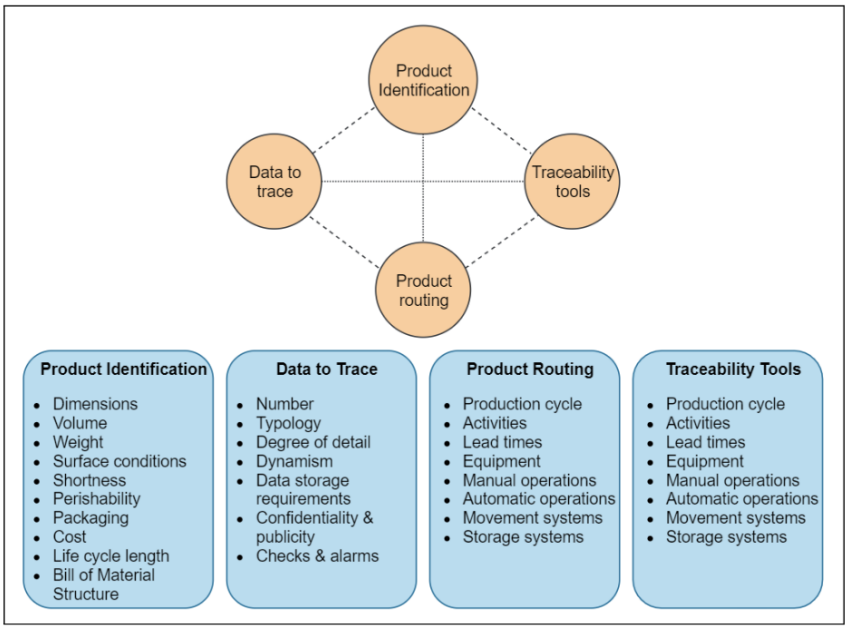

Fig. 1. Four pillar traceability framework 11; retrieved from 4.

Besides data traceability issues within the geographically distributed product development teams, the complex IT infrastructure of the organization and the complexity of the product itself are presenting challenges to managing the whole product from the SW and HW sides 12.

2.2 Product Data Traceability

The main goal of traceability is to improve the **quality of SW systems** 13. Tracing product data requires a lot of effort to document and maintain 14 and laws and regulation are different in each sector. According to 15 SW developers do not see **clear benefits of traceability** and it only challenge them with great deal of documentation effort. One of the main causes of insufficient traceability are distributed teams working with different tools with **heterogeneous interfaces** 16.

Traceability is one of the main **business benefits ALM/PLM integration** would bring to an organization 9. In other words, tracing back all the development data of the product can be accessible in one place. The SW part of the product development data is stored and managed in ALM system therefore, ALM tools enable the strong traceability in the SW development side 17. In the meanwhile, PLM ensures the traceability of the HW part of the data throughout its lifetime 18. When both HW and SW part of the product's data are managed in the respective tools, through integration the complete data of the product will be available in single platform as ALM/PLM integrated platform. This means information will be exchanged between ALM and PLM but the data itself will always store at their origin 19. By fixing the defects faster and earlier

affects the time for **launching the product in the market** 16. Thereby one of the biggest benefits of **data traceability** in system engineering are detecting the faults in the requirements or source code and fix them in a timely manner 16.
There is an urgency to have a unified harmonized global platform to manage both HW and SW development data and activity tracking. The ideal global harmonized platform should provide minimal disruption and replacement effort and involve departments/teams in the product development/delivery process so they can gain on product delivery time, respond effectively to change and efficient/errorless data sharing/reporting and not only in the organization but also with partners and suppliers in completely digital way 12. Figure 2 illustrates the potential design of how data of ALM and PLM tools can be combined in a unified platform as one true source of product data.

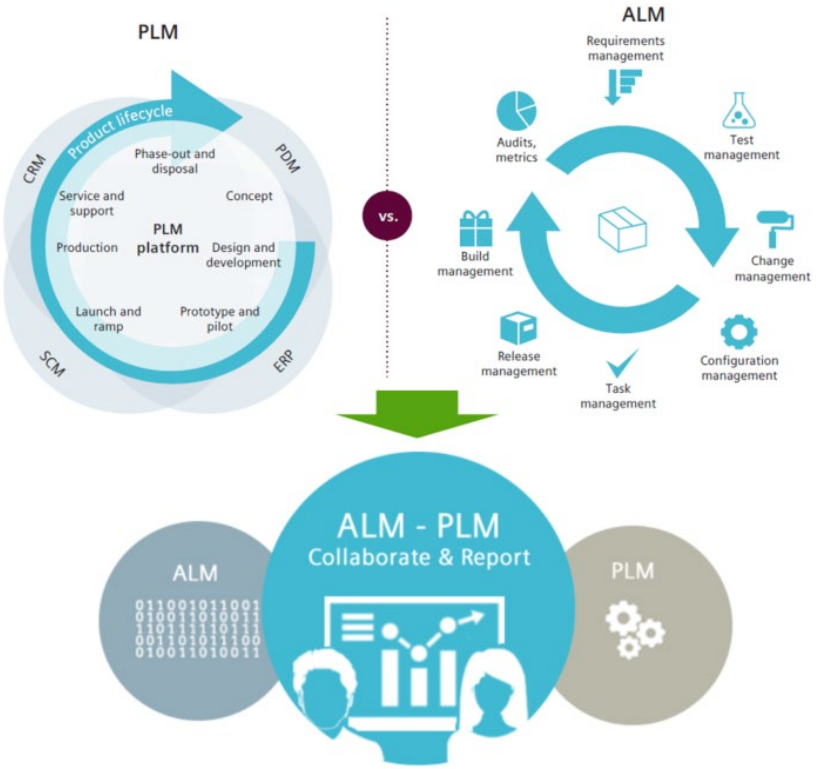

Fig. 2. Digital product data representation through PLM/ALM integration 13.

2.3 Research Gap

Research did not demonstrate developed requirements and apply them throughout an organization 14. Companies are lacking standardized guides, requirements, and realistic approaches 9

based on experience and practice to design ALM/PLM integration in their organizations' different departments 15. According to 16 analysis of both, engineering, and business benefits, such as design of data models, design of different engineering team collaboration, design of key performance indicators (KPI) and its measurement approaches are missing in scholarly articles.
Major research on traceability has been done by specific applications on **food** 10, 17, 18, **software** 10, 13, 19, 20, 21, 22 and **automotive** 23 as well as on **supply chain** 24. Recent research integrates specific technology solutions like **blockchain** 3 from operations and logistics management perspectives for "object-related end-to-end traceability" 25.
Further research is needed for "domains with complex objects, such as … manufacturing" 25 calling for validation in case studies of specific industries. There is a need for understanding benefits of integrating ALM/PLM from both, business, and engineering perspectives in the context of **production** to enhance findings from Schuitemaker 26.

Research Gap
The detailed benefits of integrating ALM/PLM from both business and engineering perspectives need to be addressed.

Research Question:
How a specific discipline (requirement engineering) of the ALM productivity can be improved via a proper tool and further gain the efficiency of it by integrating it with an PLM tool.

3 Research Method

3.1 Design Science Research

The **Design Science Research** based on 27 is applied as a choice of research design to "enhance human knowledge via the creation of innovative artefacts" 28. The developed artefact prototype is a product digitalization platform in form of an **ALM tool** as a technological solution to an important business need 29 to increase the **product data traceability**, **efficiency in cost** and **quality.**

The Design Science Research process model consists of six different steps (see Table 3), namely Awareness of a problem, Suggestion to the problem, Development of an artefact, Evaluation and feedback on the artefact and Conclusion and discussion 30.

Table 3. Six Phases of Design Science Research (own).

Research phase	Research question	Expected outcome
Awareness	By reducing the number of platforms what are the benefits coming with it?	Identify the issues of non-integrated ALM/PLM tools in literature and business

Suggestion	By reducing the number of platforms what are the benefits coming with it?	Understand the key elements to build an artefact
Development	How can system integration be applied to integrate ALM and PLM tools?	Develop ALM tool as an artefact
Evaluation	How can better data traceability, efficiency, cost, and quality be achieved?	Define where in the product development process can benefit from the artefact
Conclusion	Discussion on how literature and business requirements differ from each other and what it means for product data traceability.	Assess of the differences between literature suggestion and the artefact

3.2 Data Collection

Data was collected at an international Swiss precision instruments and service provider company with around 16'000 employees worldwide. The company provides applications for different sectors such as pharmaceutical, food and beverage, retail, and logistics.

Lifecycle management at the Swiss company is complex, with a Software Development Centre in India, dispersed teams worldwide, and at least 23 tools and five communication channels, demanding high management costs and bring quality risks. Nevertheless, there is an urgency to have a unified harmonized global platform to manage both HW and SW development data and activity tracking.

Expert interviews (n=10) within the company were conducted within dispersed ALM/PLM integration projects of mechatronic products with members from Switzerland, Austria, and India. This included meeting with the requirement engineering team as well as users. There were two different roles:

User level stakeholders (n=6): requirements engineer, project managers/team lead

Senior level stakeholders (n=4): head of R&D, head of system integration, head of software development center, head of systems and technology.

3.3 Data Analysis and Artefact Development

Interviews were recorded, transcribed, coded and data regarding requirements analyzed. Inputs from interviews were used to produce an artefact which build upon models from the literature requirements. Artefact development happened in the following phase: Learn digital tool, collect requirements from requirement engineering team, test the requirements, consolidate feedback / clarification meetings, and implement adapted requirements to further develop the artefact.

The developed artefact is based on Polarion tool and its integration to Microsoft TFS platform. It collects market requirements, translates them to software requirements, documents, gets feedback, and receives approval via the Polarion tool and then feeds into the TFS platform.

The artefact was selected between alternative options because of its most influential requirement characteristics of backward and forward trace, complete and consistent data traceability as well as visible, accessible, and clear data transparency.

4 Research Outcome on Product Data Traceability

4.1 Requirements and Characteristics of Traceability

The requirement of product data traceability can be described by different characteristics based on literature (see Table 4).

Table 4. Requirement traceability and its characteristics from literature (own).

Requirement	Characteristic	Literature quote and source
Product Data Traceability	Direction (forward and backward)	“The terms forward and backward traceability are commonly used where forward refers forward through time and backward refers to tracing data back to its origin” 26
	Consistency	"Traceability, thanks to the consistency of the data, allows to rebuild the whole history of a product keeping track of all its changes and revisions." 31
	Effort	"Labeling datasets is costly and time consuming so it is important to make them available for use within the company” 32
	Completeness	"There is a lot of traces we can stocked, that is why definition of traceability is an essential step in order to establish a predecessor-successor relationship between one work product and another, Information about each artifact, who has created or updated the artefact, users of the artefact, the source of tasks (telephone calls, documents), formal or informal texts, graphics, audio or video recordings, when was the artifact created or modified, why was the artefact created of updated etc." 19
	Visibility	"In SW engineering related areas, transparency generally refers to a product or process' visibility to stakeholders." 33
	Clarity	"A development process is visible if all of its steps and current status are documented clearly." 34
	Accessibility	"The development process is itself documented, published, and publicized so that important decisions and status are visible to all concerned parties." 35
	Technology	"Today many enterprises use some techniques and technologies to manage data traceability in several domains like RFID, barcodes, ERP,

		etc and in recent years, management SW vendors have added more features to help facilitate traceability." 19

The requirement of product data traceability with its different characteristics was then evaluated from the business side through interviews. Table 5 lists the characteristics of traceability listed from top to down by decreasing importance (number of times required by business side). The goal of this table is to show which requirement characteristics are the most required to be implemented from business side meaning that it could be the most important requirement for the users.

Table 5: Major characteristics of data traceability of business side (own).

			User level stakeholders						Senior level stakeholders				
Interview, users / Requirements	Characteristic	Keywords	I-1 ULS	I-2 ULS	I-3 ULS	I-4 ULS	I-5 ULS	I-6 ULS	I-7 SLS	I-8 SLS	I-9 SLS	I-10 SLS	Total
Product Data Traceability	Direction	product management activities, e.g. engineering change management, release management, test management	•	•	•	•	•			•	•		7
	Consistency	product quality, company reputation, audit proof process		•		•	•		•			•	5
	Effort	harmonization of HW and SW tools				•		•	•	•		•	5
	Completeness	stakeholders, external partners, cross teams/ global teams				•	•	•	•			•	5
	Visibility	transparency of success and error, culture		•		•		•	•			•	5
	Clarity	clear communication between stakeholders				•	•	•	•			•	5
	Accessability	access by all stakeholders	•	•					•				3
	Technology	tools and technologies, technology literacy						•	•				2

Traceability- Direction

By being able to easily detect errors of the past and intended use for the future can bring cost and time benefits due to having able to faster **product management activities** such as **engineering change management, release management, test management**.

Traceability-Consistency

Having the complete consistent data of a product will result in better **product quality** (less recalling of a defected product, makes it faster to fix in terms of defect detection) better **company reputation** and **audit proof process**.

Traceability-Effort

It is a chance for management to **harmonize both HW and SW tools** to be used in the company by standardizing them and manage by only through central IT service. This act will result in safer **cyber security** throughout the whole organizations especially in **global organizations.**

Traceability-Completeness

Having the complete data of the product enables all the **stakeholders** including **external partners** to be well informed and exchange right data about projects. That would mean better facilitated collaboration between **cross teams/ global teams**.

Traceability-Visibility
Visibility implication applies to the whole organization and management. Transparency of the success and error are both vital in an organizational culture. Therefore, visibility of the **project status** and **forward plan** readily and clearly available could bring a lot of efficiency and ease of daily task handling.

Traceability-Clarity
The whole transparency requirement's all characteristics are implied to management as one. Such as clear, visible, **accessible communication of any data between stakeholders of the project/ process** is the success of the management.

4.2 Comparison of literature and business requirements

In the following section, the comparison of the requirement characteristics is described. Table 6 shows a comparison between literature and business requirements. The presented requirements are listed with their chosen characteristics from interviews. Business requirements are listed with quotes from interviews and implications for management are derived.
Some of the requirement characteristics are matching in certain degrees and some of them are not representing a same goal or meaning. The direct quotes from both requirements are compared, it is possible that when the quotes are in the context.

Traceability-Direction
One of the most unexpected differences in requirement characteristics was on traceability-direction. Literature describes both directions of traceability 26, the business described more tracing backwards in terms of error tracking.

It was surprising that characteristics of accessibility and technology were of less importance to user and senior level stakeholders.

Traceability-Accessibility
Having an accessible platform to **include all the stakeholders** of a project/ process is the base of working together especially in a global organization. **Data, tool, or people** need to connect each other in every stage of an organization.

Traceability-Technology
The right choice of **tools and technologies** to be used in the workplace (**product development and production process**) can save costs.

Table 6. Comparison of literature and business requirements (own).

Characteristic	Literature quote and source	Business quote and source	Comparison of quotes	Implications for management
Direction (forward and backward)	"The terms forward and backward traceability are commonly"used where forward refers forward through time and backward refers to tracing data back to its origin" (Schuitemaker & Xu, 2020)	"I want to have a proper tool that everyone who works on the **requirement** of a product development work together simultaneously and have access to the **traceability** of the different exchanged data is maintained so we know **who did what when** in case of **error correction** needed" by Requirement engineer 1	Literature describes the both direction of traceability, the business described more tracing backwards in terms of error tracking. Matching criteria is half met.	By being able to easily detect errors of the past and intended use for the future can bring cost and time benefits due to having able to to faster **product management activities** such as **engineering change management**, **release management**, **test management** etc
Consistency	"Traceability, thanks to the consistency of the data, allows to rebuild the whole history of a product keeping track of all its changes and revisions."(Corallo et al., 2013)	"When a requirement document is written on MS Word, other **stakeholders give feedback** as comments on the MS Word document when it is circulated around but those comments are not transferred to MS Azure DevOps when the document is imported. This causes us a loss of the feedback **traceability** on the requirement." By Project manager 2	Business requirement is more focused on the early stage of product development which is including all the feedbacks and revisions of requirements before they go on to the development phase. While literature describes the whole history of the product through out the lifecycle. Early stage of product development is still a part of product history, therefore the requirements are not fully but partially matching.	Having the complete consistent data of a product will result in better **product quality** (less recalling of a defected products, makes it faster to fix in terms of defect detection) better **company reputation** and **audit proof process**.
Effort	"Labeling datasets is costly and time consuming so it is important to make them available for use within the company"(Amershi et al., 2019)	"Because if we get rid of all the middle tools used between different teams to exchange data, it is already saving a lot of time by free up their work load and creates less stress which help the people to be more efficient and effective and happy employees. It is a chance for us to get rid of the old tools which are different in different locations." By Head of Global R&D	Business requirement expresses their need to be more efficient and effective by not working with too many tools which can be replaced by a single tool. Literature mentions that having too many incompatible tools cause extremely labor intense processes. Which shows the both requirements show same meaning.	It is a chance for management to **harmonize both HW and SW tools** to be used in the company by standardizing them and manage by only through central IT service . This act will result in safer **cyber security** through out the whole organizations especially in **global organizations**.
Completeness	"There is a lot of traces we can stocked, thats why definition of traceability is an essential step in order to establish a predecessor-successor relationship between one work product and another, Information about each artifact, who has created or updated the artefact, users of the artefact, the source of tasks (telephone calls, documents), formal or informal texts, graphics, audio or video recordings, when was the artifact created or modified, why was the artefact created of updated etc."(Rahmaoui et al., 2019)	"We have to have very strong evoluted kind of reproduce any of the issues which are coming in from the market even after the development teams or anyone who has done it." by male Head of SWDC in India 1 Literature suggests the many different types of data which needs to be stored in order to have the full traceability. Business requirement exposes their need of having many different type of data storing in order to reproduce the product in case of any issue arises after the product launched in the market.	Literature suggests the many different types of data which needs to be stored in order to have the full traceability. Business requirement exposes their need of having many different type of data storing in order to reproduce the product in case of any issue arises after the product launched in the market. Business requirement states the benefit of having the complete data of the product history which matches the literature requirement explaination of importance of all the necessary data of the product.	Having the complete data of the product enables all the **stakeholders** including **external partners** to be well informed and exchange right data about projects. That would mean better facilitated collaboration between **cross teams/ global teams**.
Visibility	"In SW engineering related areas, transparency generally refers to a product or process' visibility to stakeholders." (Tu, 2014)	"I would like to see every projects current used source and how much more resource it would need until the project closes. If I have this information easily accessible it would be easier for me to plan and make decisions for the future projects based on my resource "by Head of Global R&D	In the both requirements they mention about the visibility of the process status to the stakeholders which mathces notably.	Visibility implication applies to the whole organization and management. Having visibility through out the business and one's own organization is the base of success. Transparency of the success and error are both vital for the managers to implement in their organizational culture and every day life of the company.
Clarity	"A development process is visible if all of its steps and current status are documented clearly."(Ghezzi et al., 2003)	"I would like to see each different projects' implementation rate and status " by Head of Global R&D	Both requirements state that the clear and complete documentation is important to have the transparency which benefits business for their future right decision making or being well informed about the project or process.	The whole transparency requirement's all characteristics are implied to management as one. Such as clear, visible, accessible communication of any data between stakeholders of the project/ process is the success of the management. This culture, way of work needs to be applied through out the organization.
Accessability	"The development process is itself documented, published, and publicized so that important decisions and status are visible to all concerned parties."(Bourque et al., 2004)	"The entire portfolio management, let's say if I want to look at all the projects that are active in the retail division I should be able to pull it out from a same dashboard, I can have a project manager view, team lead view and me as a head of the division I can have my own view for all the projects. By Head of SWDC in India	Business requirement explains in the literature requirement what they would like to have in their current process which is to have an access to the process or project position whenever they need to.	Having an accessible platform to include all the stakeholders of a project/ process is the base of working together especially in a global organization. If the data, tool or people are not accessible to each other it is a big concern for the management. Therefore having an accessibility in terms of every stage of the organization is management's one of the biggest task to fullfill for their organization.
Technology	"Today many enterprises use some techniques and technologies to manage data traceability in several domains like RFID, barcodes, ERP, etc and in recent years, management SW vendors have added more features to help facilitate traceability."(Rahmaoui et al., 2019)	"The reason is, it is a chance for us to get rid of the **old tools which are different in different locations**. Such as in the USA we use HP Quality Center, in India Jira and in Austria Helix is used." By Head of Global R&D	In the literature, more the mean of data collection from a physical product is described, but in the business requirement more of a product development phase from the SW point of view is described in terms of data collection and management. The matching criteria is not one to one but they have a same goal to collect and manage data.	The right choice of tools and technologies to be used in the workplace (product development and production process) would not only save costs but also result in a better employee retention rate (Rogers, 2020). Because technology literacy and getting chance to grow at the workplace is important for employees in today's technology driven world.

5 Discussion

5.1 Validity of research

To demonstrate the validity of the qualitative research, Shenton 36 requests four criteria to be applied to justify trustworthiness - to be credible, transferable, dependable, and able to confirm.
Credibility stresses the congruence of the findings with reality. Data was collected through individual interviews of one sub-organization during four months' time as part of a feasibility study on usability. The chosen interview participants were all interested in improving their process efficiency via adoption of a new tool, therefore the data bias is limited. Interviews were video recorded, transcribed and validated.
Transferability demonstrates the possibility of results to be transferred to a wider population 36. Findings are not limited to the Requirements Engineering of the Swiss company. It can be applied in other organizations with SW development processes such as test engineering or change management. In entrepreneurial realities they can scale.
Dependability criteria requires different sections in a study 36 including research design and its implementation, operational details of data gathering as well as a reflective appraisal of the project.
Confirmability demands that the result are of the "experiences and ideas of the informants, rather than the characteristics and preferences of the researcher" 36. The researcher acted as data gatherer for both, academic sources as well as business requirements. Only in the discussion phase opinion of the researcher discussed the similarities and differences between them. Furthermore, triangulation reduced investigator bias 36 since several parties were involved in the study and the developed artefact.

5.2 Business requirements

Data collected revealed alternative choices orchestrating product lifecycle data. The ideal global harmonized platform should provide minimal disruption and replacement effort and involve departments/teams in the product development/delivery process so they can gain on product delivery time, respond effectively to change and efficient/errorless data sharing/reporting and not only in the organization but also with partners and suppliers in completely digital way 12. In addition, creating a single source of truth for product design related information is a crucial benefit of the harmonized unified platform to manage both HW and SW development data and activity tracking.

5.3 Comparison with related work

In the academic field, several researchers have identified the benefits of **reducing the number of platform**s through different ways such as integration, automation or replacing the old tools. Efficiency decreases through managing different databases of a product 37. Meaning the more tools are involved in developing and producing a product, there will be more databases, where the data of those tools produced are saved. This does not bring productivity increase but decrease.

By reducing separate systems in the production productivity increases are expected. Yang et al. 38 analyzed the importance of stakeholders in relation to use of a new technology. When project stakeholders' use technology effectively, project result is positive 37. The technology efficiency is measure by automation and integration of the existing technologies in an organization. Our research also identified the importance of training for new technology of an integrated ALM tool.
From the practical point of view, several interviewees expressed their wish to decrease the number of platforms and tools, they are currently using by replacing them with a powerful and useful tool. The most efficiency they will gain are reduce the cost of licenses of different tools, proper data management in a single source rather than many different tools' database management as well as project collaboration increase in the project management.

5.4 Other observations

The development of a mechatronic product (smart product) journey requires different disciplines of systems engineering where contains HW and SW part of the product. The cross-domain engineering involves different methods, tools, and strategies to keep the smooth processes and efficiency and effectivity 9.
The study revealed various perspectives of senior manager and application manager on lifecycle management. Different levels of management in the company, as well as their functions and skills, have different perspectives on data traceability and data integration benefits.

Different level of management with different perspectives on traceability
From the business side interviews were conducted with people with **different roles** in the organization. The roles are divided into two levels:

- **User level stakeholders** are requirements engineer, team lead of requirements engineering team, project manager, project team lead.

- **Senior level stakeholders** are head of global research and development, senior manager of systems and technologies, head of integration and verification competence center, and head of SW development center.

Depending on their roles, the business requirements and their implications for their traceability need are different. Such as the requirements engineers have a very specific technical and functional requirements for the tool, whereas senior level stakeholders specify their wishes based on mostly on project management support.

Figure 3 shows the different perspectives of the two roles of a user and senior level stakeholder.

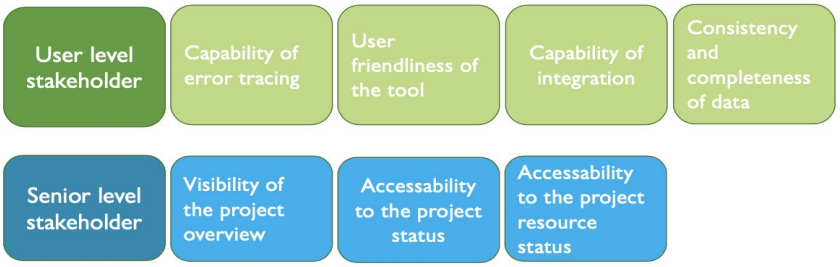

Fig. 3. Impact of different roles and functions on requirements (own).

Another specific difference which has been observed was within the **user level stakeholders**. Some of the requirements engineers require very specific functions in the tool which would help them directly on the workflow to minimize or simplify their effort. But their supervisors, requirements engineering team leads were more interested in the overall capability of the potential tool and willing to create a workaround and adjust their workflow/ process as much as they can. Meaning that the team leads were willing to be more flexible towards the new tool nevertheless the firsthand users were more strictly sticking to their current process and showed less flexibility.

Different functions impact how the tool is used

Besides the difference between the roles, another factor that caused a different implication towards the tool was the functions where the roles belong to. For example, a head of integration and verification competence center was very much focused on not to having not too many different vendor tools in their environment to reduce complexity of integrating different tools effort. In contrary, a project manager was specifically focused on a tool which can provide capability of different project stakeholders working simultaneously without losing any data or overview of the project.

Modifications by senior management

Depending on length to be part of the organization senior managers had different approaches regarding traceability and the use of an integrated lifecycle management tool. In one case a senior manager joining recently from a highly regulated background and used the ALM/PLM integration tool before, thereby knowing its organizational benefits. He pushed implementation stronger than some managers who have been working for the company in the last decade and were comfortable with the way they have been working.

In one case a senior manager claimed that they do not have any need to change their current process or tools despite other requirements engineering teams who wish to change into a better set of tools. One explanation is that either the manager is too senior to have the knowledge about his requirements engineering process pain points, or his team members are truly happy with their way of working which would suggest that they have different priorities, different from other similar function teams.

In general, the interviewees' answers towards questions were impacted by their role in the team, function, and unit they belong to, background experience they have prior and their management level in the organization.

6 Conclusion

The research confirmed that by creating a product digitalization platform through integrating PLM and ALM tools better product traceability, cost efficiency and product quality can be achieved. The study developed insights on characteristics of product data traceability of implementing a proper ALM tool as part of a life cycle management tool.

Contribution to research
The main result of the research shows, that there are sufficient improvements on product data traceability by applying one lifecycle management tool allowing transparency of processes and disciplines. This research confirmed benefits of integrating ALM and PLM to meet specific identified requirements from both business and engineering perspectives. This closes an identified lack in the literature 14.
The study's focus on collecting business requirements, analyzing, prioritizing, and communicating the implementations in the tool of choice with the users of Requirements Engineering discipline contributes to close the research gap. However, it covers one, yet very important discipline of many ALM disciplines 39. The findings suggest that traceability enables efficiency when just one tool is applied.
The developed artefact via the Polarion tool modeled the requirements identified in literature and enhanced their understanding. It tested and iterated the design of novel, more integrated systems, and tools.

Management implications
The research has shown that better data traceability can be achieved by

- Allocate resources efficiently by reducing the number of platforms
- Assign human power efficiently
- Make better decisions through transparency of the project status

Overall good feedback was received on the artefact development highlighting integration possibilities with other tools. Based on the findings of the research, there are two sets of implications for management identified to benefit of the tool:

(1) **Increase efficiency** of tool by training all users (user level and senior level stakeholders). This increased traceability of product data. For example, an auditing process becomes much easier with one tool to access and inspect for regulators. Also, this enhances collaboration between stakeholders across functionalities as well as user and senior levels.

(2) **Increase harmonization** of the tool in the organization by standardization. During the business interviews the importance of using standardized suggested tools and SWs was mentioned several times. Which means users prefer to choose tools from a company library of ready to use tools instead of searching, testing, and getting approval of the tool themselves from the upper management. There are three main benefits of standardized solution. The first, cross unit projects will have a common tool to use for their projects. Second, integrating to other SW tools within the company become easier and effortless. Lastly, users will not have to spend resource on finding the right tool for their purpose.

Limitations and further research

The limitation of the data collection (n=10) and artefact development is binded to one international company for Swiss precision instruments and services and its unit to test the artefact. Results are the point of view of a specific industry focus and size of company. From the artefact perspective, it only developed the ALM tool of the ALM and PLM integration part.

Further research is needed to study the benefits of integration through integration the ALM tool with the PLM tool in different industries and size of companies. Also, different disciplines of a smart product development process could be considered such as different areas of SW and HW to fully define the efficiency of the integration result.

Also, existing tools and standard are addressed in detail. Both are very important for the design of novel, more integrated systems, and tools. Further research could enhance the analysis of existing tools and standard of an integrated Life-Cycle-Management tool like how Aung et al did for software changes 20. Also, a categorization of the drivers and motivations as incentives of traceability systems to implement could accelerated adoption of change 24. These are based on benefits of traceability as intra-firm challenges as well as technical / system related challenges. This could be combined with specific technology used cases such as blockchain technology providing object-related end-to-end traceability 25.

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A Case Study on Teaching Social Engineering to Swiss and Cameroonian University Students in a Virtual and Cross-Cultural Setting

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Abstract. This paper presents a descriptive case study on integrating social engineering education into a business school curriculum, utilizing a cross-cultural approach. The case study was conducted at the School of Business, University of Applied Sciences and Arts Northwestern Switzerland (FHNW) in collaboration with SwissLink Higher Institute of Business and Technology in Cameroon supported by the Swiss-Cameroonian non-governmental organization (NGO) Turacos in the context of an elective module. During the six-week course, Swiss students were instructed in weekly sessions on social engineering topics and tasked with transforming their knowledge into learning materials for Cameroonian students. Subsequently, groups of Swiss students conducted virtual mentoring sessions, delivering lessons to their Cameroonian counterparts. Despite facing cultural, technological, and didactical challenges, both Swiss and Cameroonian students provided positive feedback. The study sheds light on the effectiveness of cross-cultural teaching methodologies in a virtual setting and underscores the importance of the cultural dimension of social engineering.

Keywords: Social Engineering, Cross-Cultural Education, Student Collaboration, Active Learning, Business School, Mentoring.

1 Introduction

Social engineering is a prevalent and evolving cybersecurity threat that relies on manipulating human psychology to gain unauthorized access or extract sensitive information [1]. To increase protection, social engineering should be an essential part of cybersecurity education at universities.

This paper presents a case study on teaching social engineering via a cross-cultural approach in Swiss and Cameroonian business schools, following the structure proposed by [2]: Introduction, Findings, Discussion, Conclusions, and Recommendations. This

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first section elaborates on the cultural dimension of social engineering and its relevance for students as future business managers.

1.1 Background on Social Engineering

Social engineering constitutes a multifaceted domain within cybersecurity, exploiting human psychology to compromise security. The National Institute of Standards and Technology (NIST) defines social engineering as an *"attempt to trick someone into revealing information that can be used to attack systems or networks"* [2]. Several types of social engineering, including phishing, pretexting, and impersonation target individuals' trust and manipulate them into divulging sensitive information. [3] identified for 2020 to 2022 social engineering, specifically phishing, as top crime type. The impacts of successful social engineering attacks range from data breaches to financial losses and compromised reputation, with the European Union Agency for Cybersecurity (ENISA) highlighting that targeted users stand as primary recipients of these malicious attacks [4]; moreover, the impacts can extend to physical and psychological harm [5].

Tactics, techniques, and procedures (TTPs) employed in social engineering schemes are diverse, adapting to technological advancements and evolving communication channels. Social engineering methods are commonly employed not only for initial access but also at later stages in incidents or breaches, with prominent instances including business email compromise (BEC), fraud, impersonation, counterfeiting, and, in more recent times, extortion [4]. Furthermore, the rise of phishing-as-a-service (PhaaS) due to its accessibility and affordability significantly contributes to the widespread occurrence of social engineering attacks. [6] has identified PhaaS offerings priced as low as $15 per day or a flat rate of $40 for a phishing kit (including email templates, templates of spoofed websites, potential target contact lists, guides to execute an attack, and customer support), enabling individuals with limited technical knowledge to execute sophisticated phishing attacks. Consequently, threat actors encompass a spectrum, from organized cybercriminal groups to malicious individuals, each leveraging social engineering to exploit vulnerabilities in human behavior.

1.2 Relevance of Social Engineering for Business Managers

Social engineering holds notable relevance for businesses and their managers. In the annual "Risk Barometer" study conducted by [7], the topics *cybersecurity* and *business interruption* ranked as the biggest concerns for organizations. The study unveiled that both in Europe and Africa & Middle East cyber incidents rank as the number one and two most important business risk respectively. Business managers responsible for safeguarding sensitive data face heightened risks such as phishing attacks and impersonation. The impact extends beyond financial losses to reputational damage. While accurate numbers on cybercrimes, including phishing, are not accurately measurable, due to factors such as voluntary and under reporting [8], the global financial damages for businesses and individuals are estimated to be in the trillions [3], [9]. As businesses embrace digital communication, the importance of educating students as future business managers on social engineering tactics becomes paramount. Understanding these

manipulative strategies can guide decision-makers to implement proactive measures, fortifying organizational defenses and fostering a resilient cybersecurity posture.

1.3 Relevance of Cybersecurity and Social Engineering for Cameroon

The surge in digitalization across African nations has led to a rapid increase in internet accessibility, presenting both opportunities and challenges for organizations. During the second quarter of 2023, Africa witnessed a significant 23% year-over-year surge in weekly cyber-attacks per organization [11]. Particularly, Cameroon (ranked 81st on the Cyber-Safety Index) emerges as a high-risk area for cyber threats [12]. This underscores the urgent need for cybersecurity experts and innovative solutions to bolster organizational resilience. However, many African countries lack comprehensive cybersecurity education [10] with limited programs available in both public and private universities.

In Switzerland, cybersecurity curricula often emphasize technological and organizational aspects [13], yet they often neglect the human element, particularly the cultural dimension [14]. Research findings highlight however, that culture plays an important role in shaping attitudes towards privacy and security [15], emphasizing the need for cross-cultural research, especially in social engineering. In this context, [16] argue that a cost-effective approach to enhancing cybersecurity capabilities in low-income countries involves focusing on the social and cultural dimensions.

1.4 Context of the Case Study

This case study is situated at the FHNW School of Business, which aims to develop innovative specialists and managers for the evolving global landscape [17]. The school offers a bachelor program in business information technology (BIT), with students able to choose electives valued at 3 ECTS each, spanning six weeks with weekly four-hour lectures. Although there is a mandatory IT Security course, a dedicated social engineering elective has been newly introduced by the Competence Center Digital Trust[1]. This course is supported by SwissLink Higher Institute of Business and Technology[2] (short: SwissLink) and Turacos[3], a non-governmental organization promoting cross-cultural exchanges and cybersecurity education in Cameroon. While SwissLink provides business and engineering courses, the university curriculum offers no dedicated course on cybersecurity. Hence, the collaboration with FHNW and the aim to bridge this gap by equipping students with relevant cybersecurity knowledge.

1 https://digitaltrust-competence.ch
2 https://swisslinkedu.com
3 https://www.turacos.ch

2 Findings

This section provides deeper insights into the learning objectives, the design and implementation of the social engineering course.

2.1 Course Objectives

Our course stands out from traditional social engineering courses by integrating it into cultural contexts and fostering cross-cultural skills in a virtual setting. We aimed to make the cultural aspects of social engineering tangible through direct exchanges with students from Switzerland and Cameroon. The course draws inspiration from the concept of Collaborative Online International Learning (COIL), emphasizing the creation of an environment conducive to cultivating cross-cultural skills through IT-enabled connections between classrooms situated in different geographic locations [11]. The detailed course objectives are outlined in **Table 1**.

Table 1. Learning objectives of the social engineering course (Swiss perspective)

Learning Objective	Description
Knowledge and understanding	Students demonstrate profound knowledge and understanding of social engineering concepts, tactics, and countermeasures encompassing techniques like phishing, pretexting, and impersonation. They also cultivate awareness of the cultural aspects of social engineering and its implications on individuals, organizations, and society.
Application of knowledge and understanding	Students can craft culturally and contextually relevant learning materials by understanding the social and cultural dynamics in Cameroon. This enables them to customize educational content to align with local perspectives, norms, and communication styles effectively. Students display proficiency in leading mentoring sessions for Cameroonian students, emphasizing the identification and application of suitable methods. They acquire skills to evaluate the educational needs, cultural intricacies, and technological resources of the Cameroonian student body. This enables them to adjust mentoring approaches to promote engagement, comprehension, and knowledge retention effectively.
Ability to reflect	Students exhibit the capability to reflect on their mentoring sessions, conducting thorough analyses to recognize successes, challenges, and areas for enhancement. They cultivate the ability to objectively evaluate the effectiveness of their strategies, considering participant engagement, comprehension, and learning outcomes. This fosters a mindset of continuous improvement, empowering students to enact constructive changes in subsequent mentoring sessions.

2.2 Course Design

To design the course content the ACM Curricula Recommendations on Cybersecurity [13] shed light on the essential components of a well-rounded education in this field. The topics *"types of social engineering attacks," "psychology of social engineering attacks," "misleading users,"* and *"detection and mitigation of social engineering attacks"* form its cornerstone. In alignment with these recommendations, our course incorporates each of these topics. However, we go a step further by integrating additional subjects tailored to the Cameroonian environment. Recognizing the evolving landscape of cyber threats and societal challenges unique to our context, we include in our curriculum the exploration of "mobile money" (*"a recent innovation that provides financial transaction services via mobile phone, including to the unbanked global poor"* [14], with most users being in Sub-Saharan Africa (22%) and of those 27% being in West Africa [15]) and "fake news".

The design of the course is outlined in **Table 2**. It is structured into six weekly lectures, each covering one specific topic in the field of social engineering.

Table 2. Design of the social engineering course

Topic	Description
1. Introduction	Joint one-hour online session with Swiss and Cameroonian lecturers and students, aimed at conveying the course context, conditions, and a first introduction of both student parties. Swiss students also received an introduction into the Cameroonian culture followed by a first input lecture of the topic *social engineering kill chain*.
2. Phishing	The focus is set on *phishing* as a key threat in the field along with its various forms, including, Smishing, Vishing, and QRishing, the motivation and impacts to individuals and businesses, and the TTPs employed by threat actors.
3. Mobile Money	*Mobile money*, a financial service facilitated through mobile devices, is crucial in Africa for its role in bridging banking gaps and facilitating financial inclusion. Mobile money services expose users to social engineering risks, as fraudsters exploit human vulnerabilities through manipulative tactics, posing a threat to their financial security.
4. Fake News	*Fake news* involves disseminating misleading or false information to deceive and manipulate public opinion. In Africa, fake news holds significance due to its potential to influence political dynamics, exacerbate social tensions, and impact public trust. Social engineering exploits human psychology, often through misinformation, to manipulate individuals into divulging sensitive information or taking certain actions.
5. Internet Hygiene	*Internet hygiene* involves adopting safe online practices. In Africa, where digital connectivity is rising, promoting internet hygiene is crucial for safeguarding personal data and privacy. Social engineering exploits human

	psychology online, emphasizing the need for heightened awareness and education to counteract cyber threats in this evolving digital landscape.
6. Closing	Joint one-hour online session with Swiss and Cameroonian lecturers and students, aimed at summarizing the learning content and reflecting upon the learning journey. The Cameroonian students that successfully finished the course were awarded with a certificate. After feedback from the Cameroonian students, an interactive feedback session with Swiss students followed.

The course structure was comprised of one-hour input sessions by the lecturer, where Swiss students received topic-relevant content. Subsequently, the Swiss students were allocated dedicated time to craft their learning materials, allowing for the application of theoretical concepts. The culmination of each session involved a feedback mechanism, where lecturers provided feedback and evaluations on the created learning material. This cyclic process of input, creation, and feedback aimed at fostering a dynamic learning environment, ensuring students not only absorbed theoretical knowledge but also actively applied it, receiving constructive guidance to refine their educational materials.

The Swiss students were instructed to self-organize with their peers in Cameroon about the time and modality of the mentoring session. After each mentoring session, Swiss students were required to deliver a reflection report on the mentoring sessions, including their successes and challenges, and improvements to the learning material and mentoring session.

2.3 Course Implementation

The course took place from the 13th of November 2023 to the 18th of December 2023, with 27 Swiss and 23 active Cameroonian participants. Turacos facilitated the formation of groups and the collection of reflection papers from Cameroonian students. Swiss students were organized into groups (two to three students), with each group assuming the role of mentors for Cameroonian students. Simultaneously, Cameroonian students were assigned to specific Swiss groups, fostering a collaborative learning environment. Communication was facilitated through a dedicated WhatsApp or Telegram group, enabling students to coordinate mentoring sessions, discuss weekly content, and plan meeting schedules. This approach not only enhanced the sense of community but also provided a platform for effective cross-cultural exchange.

The students demonstrated a high degree of adaptability to the various challenges they faced preparing and conducting the mentoring sessions. Exemplarily, they chose modalities that best suited their respective groups, especially to circumvent challenges with the poor internet connectivity in Cameroon, ranging from sharing slides and assignments in the WhatsApp channel to conducting Google Meet sessions if possible. Email correspondence was also used to communicate between the groups. The learning materials were not only created based on the weekly input but were also tailored to suit the cultural nuances of the Cameroonian audience. Additionally, Swiss students

designed assignments, such as weekly quizzes and topic-specific homework, to reinforce the learning experience.

Evaluation of the students' learning materials was conducted by lecturers using a comprehensive set of criteria. The criteria included assessing how well the materials were adapted to the target group, evaluating the planning of interaction with the target group, verifying the correctness and currency of the content, assessing the persistence and flexibility in mentoring, and examining the reflection and lessons learned from the process. Notably, the Cameroonian students, as one essential stakeholder, were not subject to formal evaluation, as the course was offered free of charge and did not result in ECTS credits. However, the Cameroonian students had to partake in their mentoring sessions and submit weekly reflection papers to receive a certificate of attendance at the end of the course. Overall, this innovative approach to cross-cultural education reflects the commitment to inclusivity and mutual learning.

3 Discussion

This section is dedicated to learning and feedback from the lecturers and students. Positive aspects are elaborated and fields for improvement are identified and discussed.

3.1 Lecturers' Learning and Feedback

The positive feedback from lecturers supports the continuation of the course, led by three FHNW teachers collaborating to enable mutual learning and improvement. This team approach brought together subject matter experts on social engineering and cross-cultural exchange, benefiting students by leveraging the diverse skill set of the lecturers. Teaching as a group enhanced efficiency, enabling parallel feedback for the student groups, and offering a range of perspectives on learning material. Additionally, the course provided lecturers with opportunities to expand their cultural competence through interaction with students from different countries. While this collaborative teaching model is not common in universities and poses cost-effectiveness challenges, personal commitment made it feasible for three lecturers to participate initially. Future offerings may require additional resources and could potentially involve fewer lecturers as experience grows. However, effective management of stakeholders and interactive settings will always demand significant involvement from the lecturers. Coordinating the course for the first-time posed challenges in group management and coordination.

Moreover, educators and coordinators from SwissLink and Turacos underscored the importance of this course, especially for Cameroonian students. It provides them with the opportunity to engage in an international program from their home countries. This alleviates the financial burden of travel expenses that often deter some from pursuing such opportunities.

3.2 Swiss Students' Learning and Feedback

Swiss students submitted weekly reflective papers about their mentoring sessions with their Cameroonian peers. These papers were submitted via the FHNW's study portal – Moodle. Based on the collected reflective papers, the Swiss students' learning journey aligns with the classical four-phase model of cultural learning: Honeymoon, Crisis, Adjustment, and Adaptation [16].

Honeymoon Phase: Most students were very enthusiastic about the meaningful cultural exchange, as highlighted by the quote: *"The [Cameroonian] students' keen interest in more information was encouraging, signifying the session's success and the need for ongoing education in cybersecurity. This mentoring experience was a chance for knowledge exchange and a meaningful opportunity for cultural interaction, emphasizing the importance of cross-cultural communication in education, particularly in dynamic fields like cybersecurity."*

Crisis Phase: Swiss students experienced heightened insecurity and overwhelming responsibility in organizing mentoring sessions independently. This pressure led to frustration and the need for lecturer support, necessitating solutions tailored to individual needs, such as reorganizing group assignments, reaching out to lecturers in Cameroon, and lecturer participation in mentoring sessions. Further challenges arose due to e.g., technical issues, leading to frustrations among Swiss students. Support from lecturers was crucial in finding solutions.

Adjustment Phase: Students made significant efforts to adjust. This involved rescheduling, recording, or transitioning mentoring groups to asynchronous mode. During this phase, Swiss students gained valuable experience in cross-cultural collaboration. For instance, they found success in improving the interaction by individually reaching out during mentoring sessions to gather feedback, despite the cultural norm in Switzerland, where singling out individuals from a group may be seen as impolite.

Adaption Phase: Most groups adapted well to the collaboration process, recognizing that it operated differently from their accustomed methods in Switzerland. A high level of reciprocal learning between Swiss students and their Cameroonian peers took place. Notable was the exchange of insights on mobile money fraud, a prevalent topic in Cameroon.

Overall, as evidenced by the following quote, the mentoring approach combined with a virtual setting proved highly effective for learning both the subject matter of social engineering and soft skills, as well as fostering cultural understanding: *"Stepping into the shoes of a mentor was both challenging and rewarding. This role reversal also highlighted the importance of empathy, patience, and adaptability in guiding others through their learning journey. Organizing the mentoring sessions demanded a new set of skills."*

3.3 Cameroonian Students' Learning and Feeback

As aforementioned, Cameroonian students submitted reflection papers via email to Turacos. Despite the technical challenges of partaking in a virtual course, the

Cameroonian students nonetheless could benefit. The key lessons that the students highlighted in their reflection papers include:

Ability in handling sensitive information: Some students mentioned that not only have they learned how to interact with sensitive information on social networks, but they have also learned how to securely store such information. *"This exercise will help me on how to use and interact with sensitive information on social networks and the importance of discretion when storing data."*

Improved cyber threats awareness: Despite ongoing frauds in Cameroon, cybersecurity is not a topic commonly discussed among students. Following their participation in the course, the students pointed out that they have become more conscious of cyber threats and have developed a proactive mindset in guarding against cyber threats and unsolicited emails. *"With this exercise I have gotten to understand how cyber attackers do get information about their target using platforms like Facebook, Google, and Instagram. I have also learned about what open-source intelligence is and how both the cyber attackers and cyber security professionals use this in their daily routine."*

"This topic is relevant to my personal life as an individual and my career. This is because with this knowledge so far, I now know what social engineering is and what the impacts are, and the motivations of social engineering threat actors. Talking about phishing and learned that I need to keep my accounts safe by using additional authentication methods to avoid such attacks."

Guarding against fake news: It is common for people in Cameroon to get their news from Facebook and WhatsApp. Hence, the dangers of fake news were also a valuable lesson for the Cameroonian students.

Some wrote that they have learned how to carefully vet new sources before sharing the news. *"My key takeaways include the importance of scrutinizing sources, promoting responsible sharing of information, and the need for regulatory measures and cooperation between tech companies and policymakers to proactively address fake news."*

In the final session, a few Cameroonian students also expressed positive feedback towards their Swiss mentors. They appreciated especially the ability of the Swiss students to pass the content in a clear manner.

4 Conclusion

4.1 Concluding Summary

Examining the Social Engineering course critically revealed certain limitations in its
In response to the escalating global challenges posed by social engineering and cybersecurity threats, there is an increasing emphasis on continuous education and awareness training. Organizations worldwide recognize the imperative of equipping individuals with the knowledge and skills necessary to navigate the evolving landscape of digital risks. Ongoing education and awareness training in social engineering and cybersecurity play a pivotal role in addressing global challenges in the digital landscape. These

initiatives, crucial for both individuals and organizations, serve as proactive measures against evolving cyber threats. Notably, international collaboration, as exemplified in the case with Cameroon, underscores the potential for cross-cultural exchanges to enhance understanding and fortify collective defenses. This collaborative approach is particularly beneficial for students not directly enrolled in cybersecurity courses, providing them with essential knowledge and skills to navigate the increasingly interconnected digital world.

By fostering a culture of cybersecurity awareness and education, we contribute to a more resilient global community better equipped to confront the multifaceted challenges posed by social engineering and cyber threats. The collaboration between the FHNW, the SwissLink University and Turacos proved to be successful, resulting in reported increased awareness and understanding of social engineering threats and countermeasures, delivered through modern technological communication channels in the form of online classrooms.

By achieving the learning objectives as outlined in section 2.1 the course allowed Swiss students to solidify their knowledge and understanding of Social Engineering by adopting the role of a mentor and to gain cultural experience of Cameroon and Cameroonians.

4.2 Limitations

Examining the course critically revealed certain limitations in its design, execution, and educational context.

Course design: In this first iteration, a lot of unknown and limiting factors had to be covered in the course design. As an example, it was not possible that the Cameroonian students were granted with ECTS. Hence, their commitment to stick to a six-week course was hard to predict in advance. This led to a setup that would allow the Swiss students to complete the course despite a potential drop-out of the Cameroonian peers. This design was useful for the start. However, it placed FHNW into the teacher and SwissLink into the learner role; this did not reflect reality. As for example, for the topic of mobile money fraud, the Cameroonians were the experts and provided background and practical cases. In future, the course design should be adapted to foresee both institutions and their participants as learners and teachers simultaneously.

Course execution: One limitation in executing the course was the infrastructure. A particular constraint was the inadequate internet accessibility in Cameroon for participating in mentoring sessions beyond school hours. This constraint might have impeded the engagement of students, particularly those who faced challenges accessing online resources outside of the educational institution.

Educational context: It was a challenge to handle the various familiarity levels among participants. While some students found the course content entirely new, others expressed prior knowledge. To address this, there is a future need for a more nuanced approach, allowing more advanced students to delve deeper and ensuring a balance that caters to the diverse backgrounds of both sets of participants.

These limitations highlight the importance of considering contextual factors, such as internet accessibility and tailoring content to accommodate varying levels of familiarity, to enhance the overall effectiveness and inclusivity of the social engineering course.

5 Recommendations and Future Research

In reflecting on our course and considering avenues for improvement and future research, several key recommendations emerge.

Firstly, building upon the foundational knowledge that some students bring as preknowledge, our focus should be on adapting the course content to facilitate deeper learning. This adaptation could involve incorporating advanced concepts, case studies, and real-world examples that resonate with Swiss students, thereby enhancing their engagement and understanding.

Secondly, to enhance motivation, we propose granting all students ECTS and linking the certificate of attendance to specific requirements, e.g. completing assignments, or achieving a mandatory attendance rate. This approach not only incentivizes active involvement but also ensures that participants are fully immersed in the learning process, thereby maximizing the benefits derived from the course.

Furthermore, recognizing the limitations concerning internet connectivity, we propose the establishment of dedicated time slots for the mentoring sessions. By aligning these sessions with Cameroonian school hours, we aim to provide students with optimal conditions for participation, including access to a stable internet connection and reduced scheduling conflicts.

In addition to these practical considerations, our ongoing research includes the measurement of Information Security Awareness using the Human Aspects of Information Security Questionnaire (HAIS-Q) [17]. By employing this tool, we seek to assess the effectiveness of our course in enhancing participants' awareness of information security practices and principles. Importantly, we intend to analyze the results from both a *a priori* and *posteriori* perspective, allowing us to gauge the impact of the course over time and identify areas for refinement and improvement, ensuring that the course remains relevant, engaging, and impactful.

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Big Data Analytics Implementation Risks Conceptual Model

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Abstract. Small and Medium Enterprises in South Africa may need to adopt emerging technologies such as big data analytics to enhance growth strategies, enabling employment, creation, and meaningful contributions to economic development. This study aims to investigate big data analytics risk management factors and develop a model for managing implementation risk in small and medium enterprises. A conceptual model for managing big data analytics implementation risks in Small and Medium Enterprises is proposed based on a literature review on big data analytics implementation risks. The proposed conceptual model may provide new insights into supporting SMEs' big data analytics implementation. The overall practical contribution of this study is to assist SMEs with the big data analytics implementation risks model. Literature shows that research has been conducted on big data analytics implementation risks in SMEs.

Keywords: Big data analytics, big data analytics risk factors, SMEs.

1 Introduction

1.1 Big data analytics

Big data analytics in an increasingly digital environment represents the potential for Small and Medium Enterprises (SMEs) to navigate and survive in this changing environment. As such, there is growing interest in big data analytics from academia and industry [1, 2]. However, implementing data analytics projects is risky [3, 4] with project failure rates estimates running over 80% [4]. Furthermore, implementing big data analytics projects introduces additional company risks [4]. Nevertheless, despite the implementation risks and high project failure rates, big data analytics are critical in Small and Medium Enterprises. Big data analytics may be defined as the process of collecting and systematising massive and varied data [5, 6] and applying advanced

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analytic techniques [7, 8] to uncover hidden patterns [9, 5, 6, 10]. Moreover, big data analytics supports the identification of unknown correlations, market trends, customer preferences and other helpful information [11] to enhance decision-making [12, 9, 6] productivity and innovation [9]. In addition, big data analytics relies on structured and unstructured big data [10] to discover knowledge and intelligence [5, 9].

There are several benefits to using big data analytics. According to [7], big data analytics presents several benefits to companies in generating accurate business insights and understanding. Furthermore, big data analytics enables enhanced customer targeting [7], supporting the acquisition of new customers [13], markets [7] and customer retention whilst improving customer service. In addition, big data analytics empowers companies to quantify market sentiment [7]. Moreover, [12] big data analytics allows better decision-making by transforming low-value raw data into high-value information and higher product and service quality. Furthermore, big data analytics increase operational efficiencies [12, 13, 14]. As big data analytics supports business process optimisation [12], enhancing planning, forecasting and identification of root causes of cost [7], thus reducing cost [12, 6].

Big data analytics are vital in enabling competitive advantage. As big data analytics provide users with a consolidated view of data from multiple data sources [6], facilitating informed strategic direction [13], competitive differentiation through innovation and the creation of new products [13]. Furthermore, big data analytics presents new opportunities for fraud detection and risk quantification [7], enhancing revenue growth and profitability. Furthermore, big data analytics enables automated decision-making support [7]. Similarly, big data analytics enhances organisational efficiency [15, 12 , 13] and speed, enabling access to refined, processed data for improved decision-making [5].

In SMEs, big data analytics represent untapped potential. According to [16], As digital technologies such as big data analytics provide new opportunities for Small and Medium Enterprises to participate in the global economy, innovate and grow [6]. The analytical potential of big data can help Small and Medium Enterprises to be innovative and engage in the global economy [17]. However, big data analytics are not sufficiently used in Small and Medium Enterprises [18]. In South Africa, about 22 200 results in big data analytics implementations within Small and Medium Enterprises [4]. Big data analytics offer substantial benefits in Small and Medium Enterprises when successfully implemented [7].

The paper bridges the gap identified in the literature on the challenges and risks of Small and Medium Enterprises to gain more insight through leveraging big data analytics. The paper's basis will help contribute to the big data analytics field within SMEs. The paper contributes to the theoretical gap by answering the research question: What is the potential conceptual model for managing big data analytics implementation risks. Furthermore, shares insightful recommendations that could assist Small and Medium Enterprises, incubators, researchers, industrial practitioners, big data providers, and governments in the big data analytics area on the challenges of the current big data analytics implementation risks [3] linking the risks management with Small Medium Enterprises Owner-manager characteristics for an enhanced approach that more that takes into account individual owner manager innovation characteristics. To strengthen the study, the study integrated the attributes of TOE and owner manager innovation characteristics.

The contribution of the study seeks to make a theoretical and practical contribution on managing big data analytics implementation risks and generate new insights that may be of value in supporting SMEs big data analytics implementation endeavours. Furthermore, the practical insights generated from the study may be of value to SMEs, big data analytics providers, and institutions providing SMEs support services to SMEs inclusive of governments. SMEs and other organisations may use the proposed model in assessing big data analytics implementation risks and derive strategies for overcoming potential risks, reducing big data analytics projects failures. The study bridges the gap identified in the literature on the challenges of SMEs to gain more insight through leveraging BDA. The basis of the study will help to contribute to the field of BDA within SMEs.

The study contributed to the field of big data analytics. It fills the gap by developing a model for big data analytics implementation risks. Further, an insightful recommendation that could assist researchers, industrial practitioners, big data providers, and governments in big data analytics area on the challenges of the current big data analytics methods, and solutions that would alleviate these challenges has been addressed by researchers such as [12]. This study will follow a systematic research process methodology as discussed by several researchers, ensuring that the set aim will be achieved. This model will be used not only by SMEs but also by other organisations to make decisions related to big data analytics. Literature shows that research has been conducted on big data analytics implementation risks in SMEs. This study aligned the theoretical model to big data analytics implementation risks model. This study will use positivist approach which is quantitative.

Despite big data analytics' potential to support SMEs' digital transformation endeavours, and the SMEs need to use big data analytics to learn more about and value from big data [15]. SMEs face challenges implementing big data analytics managers with high project failure rates. Furthermore, one of the main challenges in using big data analytics is managing implementation risk in big data analytics projects with big data analytics, having unique risks such as the possibility of predictive model bias, that may negatively affect the organisation deploying the big analytics projects [16]. As such, the proposed research seeks to respond to calls for additional research on managing big data implementation and contributes to research on big data analytics project risk implementation.

1.2 Big data analytics risk factors

The successful implementation of big data analytics will entail overcoming big data analytics implementation risks. Technological risk factors are one of the main elements in big data analytics implementation. technological risks are one of the most critical threats due to the considerably increasing complexity of digital technologies [19]. Big data analytics implementation technological risk factors include infrastructure and development cost, data privacy and security and data quality [20]. Based on the importance and necessity of infrastructure for the effective big data application, SMEs should attach importance to increasing investment in big data related equipment and facilities to lay a solid foundation. Big data technologies offer numerous opportunities, and its potential is undeniable. However, data scientists are facing different challenges

when dealing with large data sets to dig out knowledge from such mines of information. [21], indicated that challenges exist at different levels such as data capture, storage, searching, sharing, analysis, management, and visualization. Additionally, distributed data driven application of big data technologies also face security and privacy issues. SMEs consider data security issues more serious than large firms. This is because SMEs lack the kind of environmental conditions and IT expertise that large firms enjoy [22]. SMEs should focus on improving the standardization of management, especially strengthening the management of data, improving the overall data quality. Monitor data quality by statistical process control to avoid sudden deterioration of data quality and negative impact on data or even business caused by abnormal values and provide enterprises with more comprehensive and accurate data in order to lay a solid foundation for the efficiency of big data application.

In the current era of unmatched technological advancements, the effective use of big data analytics has become a fundamental requirement for organizations and provides opportunities for managing risks to increase competitiveness and enhance performance and productivity [23]. However, implementing big data analysis entails risks so it is important that users develop deeper understanding of the risks in order to generate innovative strategies to overcome the challenges. Technological risk factors include but not limited to complexity related to data and technology, poor quality and unorganized data, technical uncertainty, privacy and cyberattack risks/security issues, scalability risks as well as minimal technological resources and infrastructure support [22]. According to the results, managers are made to understand that technological risks are the most severe risks that need to be given much more attention when organizations are seeking implementation of big data analytics. Due to infrastructure challenges in emerging economies, the choice of technology must be given serious thought in order to ensure that the right choice of technology which is compatible with the existence infrastructure is selected.

In addition to technology in implementing big data analytics, Small and Medium Enterprises would need to overcome organisational risk factors. Organisation risk factors include management support, organisational culture and resource availability [20]. Management support comprises executive sponsorship and critical stakeholder support, while organisational culture comprises a well-defined strategic vision, organisational learning culture and open and analytical organisational culture [20]. Prior studies have indicated that top-management support is a critical driver of new technology adoption [6]. However, in SMEs, owner-managers were reported to lack willingness to implement new systems [24]. Resources would address functional and systems support, team skills and competency dedicated to big data analytics [20].

In implementing big data analytics, the environmental risk factors refer to the external macro environmental conditions, including regulatory and competitive pressure [14]. Regulatory pressure refers to government policies, laws, incentives, guidelines, and industry norms affecting digitalisation [9]. Competitive pressure originates from changes in other competition [14]. Increasing big data usage among competitors could work to pressure the owners and managers to capture business analytics and intelligence to obtain and maintain a competitive market status [8].

Big data analytics implementation process may have inherent process risk factors. Big data analytics may evolve with three challenging and interrelated processes: data

understanding and preparation, model building testing and evaluation and model deployment [20].

SME owner-manager characteristics may affect managing big data analytics implementation risk. The diffusion of innovation theory presents a valuable lens for examining owner-manager characteristics' influence in managing big data analytics risks. The diffusion of innovation theory is often regarded as a helpful change model for guiding technological innovation where the innovation is modified and presented in ways that meet the needs across all levels of adopters [25]. The innovators may be categorised into five categories based on the S-curve: innovators, early adopters, early majority, late majority and laggards [26]. Furthermore, adopters' distributions follow a bell-shaped curve and, over time, approach normality. At the initial stage, only a few innovators are open to the new idea and adopt its use, followed by early adopters that are perceived to be opinion leaders and the early majority that adopt new ideas just before the average member of a social system [26]. The innovators' characteristics are expected to influence managing big data analytics implementation risk. Innovators are technology enthusiasts, and early adopters are visionaries, with the early majority being pragmatists [25]. Innovators are eager to try new ideas and accept an occasional setback. The innovator plays an essential role in the diffusion process of launching a new idea in the social system by importing the innovation from outside the system's boundaries. Innovators are cosmopolites and may cope with higher levels of uncertainty. The resulting distribution is an S-shaped curve when the number of individuals adopting a new idea is plotted on a cumulative frequency over time. Only a few individuals adopt the innovation each time, which can be in a year, week, or month; such are innovators [27]. Thus, innovators are most likely to proactively manage risks, accept higher risk levels, and develop contingency plans when implementing cutting-edge big data analytics technologies and methodologies to pursue potential benefits while mitigating setbacks.

Early adopters usually have higher socioeconomic status. A significant adopter incentive is paid to acceptors; individuals of the lowest socioeconomic status seem to be the most innovative [27]. Nonetheless, incentives increase the number of adopters of an innovation, and the quality of such adoption decisions may be relatively low, leading to limitations in the intended consequences of adoption. Early adopters are localities and have the most significant degree of opinion leadership. Potential adopters look to early adopters for advice and information about the innovation [28]. Change agents generally seek them to be local missionaries to speed the diffusion process. Early adopters are not too far ahead of the average individual in innovativeness [27]. Early adopters serve as role models for many other social system members. The early adopter is respected by his or her peers. Peers respect the early adopter and make rational innovation decisions [28]. So, the role of the early adopter is to decrease uncertainty about a new idea by adopting it. Relatively earlier adopters perceive trialability as more critical than do later adopters. Early adopters are most likely to take a balanced risk management approach, seeking proven results in big data analytics by conducting thorough risk assessments and implementing targeted risk mitigation strategies to minimise potential negative consequences.

The other adopters' categories are the late majority, that adopt new ideas just after the average member of the social system, and laggards, that are the last in a social system to adopt an innovation [26]. The late majority may be called conservatives, while laggards may be referred to as sceptics [25]. The early majority adopt new ideas

just before the average member of a social system. The early majority's unique position between the very early and the relatively late to adopt makes them an essential link in the diffusion process. They provide interconnectedness in the system's networks. The early majority may adopt a cautious approach to big data analytics implementation risk, preferring tried-and-tested solutions with predictable outcomes, and may utilise risk transfer mechanisms like insurance or outsourcing to minimise exposure to potential losses.

The late majority adopt new ideas just after the average member of a social system. Adoption may be both an economic necessity and the answer to increasing network pressures. Innovations are approached with a sceptical and cautious air, and the late majority does not adopt until most others in their social system have done so [3]. The late majority could take a reactive risk approach to managing risks associated with big data analytics implementation, focusing on risk mitigation measures to minimise potential negative impacts on operations and a risk management approach that may be driven by the need to comply with industry standards and regulations.

According to [27], Laggards refer to the classification method of adopters as not symmetrical in this category. Laggards take a passive, risk-avoidant approach to managing risks associated with big data analytics implementation, prioritising traditional methods and resisting change to maintain the status quo and minimise exposure to potential risks; hence, resistance to change and preference for maintaining the status quo may outweigh willingness to address the risks actively. Innovators and early adopters could be combined into a single class to achieve symmetry, but their different characteristics mark them as two distinct categories [27]. The adopter's categories are illustrated with the estimated percentage of each category in the bell-shaped curve diagram below.

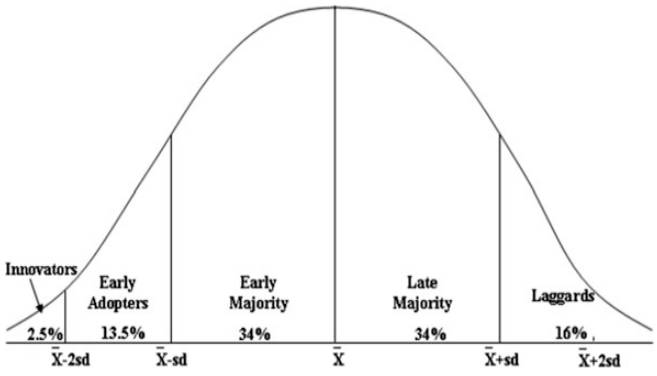

Fig. 1. Diffusion of Innovation Adopter Categories [26]

1.3 Knowledge gap

Big data analytics is a growing body of knowledge. [28] highlighting a growing interest in research and application of big data analytics in organisations. A significant amount of research in big analytics is conceptual, seeking to advance knowledge in big data analytics, such as understanding platforms, definitions and technologies [15]. Additional studies have proposed theoretical frameworks for utilising big data

analytics in education [10]. Furthermore, in order to address significant big data issues, open research concerns, and various methodologies. In addition, a literature review on big data analytics studies was conducted [14] a as well as a review of open challenges and techniques [12]. Additional, theoretical research focused on prominent theories used in supply chain management using big data analytics [29]. In the previous studies, four frameworks for big data analytics were identified but only two of the frameworks were relevant to managing implementation risk [2].

Empirical research on big data analytics is developing, such as examining the difficulties in implementing big data within SMEs [17]. The effect of organisational issues on extensive data analytics adoption [12] and the significant data analytics impact on enhancing organisational performance. Furthermore, the effects of technological, organisational and environmental factors on big data analytics adoption among SMEs were examined [18].

Research is beginning to emerge on the risks associated with big data analytics, investigating the barriers facing SMEs in adopting big data analytics and proposing ways to mitigate the barriers and exploit opportunities of big data analytics [2]. The majority of studies in the field of big data analysis have been conceptual in nature, examining big data's definition, risk factors associated with methods and tools [12], as well as the analysis responsibilities that fall under big data analysis areas inside organisations [5]. The emerging empirical research on big data analytics implementation risk mostly used qualitative [12]. Furthermore recommendations are made for quantitative studies examining the theories behind big data analytics [17]. More still, research on big data analytics in the SME's context have highlighted that most SMEs are still not clear on how to analyse big data [10].

Risk implementation in SMEs have made some progress in gaining insight based on previous studies [4, 17]. Moreover, studies on strategies to overcome the risks encountered while integrating and implementing big data analytics within SMEs areas [10]. A model for managing big data analytics implementation risk in SMEs based on the literature on SMEs and big data analytics was designed.

A call for research on big data analytics implementation risk have been made which led to the development of a potential model to address the gaps. Moreover, recommendations have been made for research that takes a holistic approach to data analytics implementation, not only focusing on technology aspects [10]. Furthermore, calls have been made for research on managing big data analytics risk [18], identifying explicit data analytics risks, and developing management processes at both the project and executive levels for mitigating or eliminating data analytics project risks [4].

1.4 Methodology

This section discusses the literature review that was followed as scoping and exercise on the big data analytics implementation literature. A literature search was conducted to identify pertinent literature in managing big data analytics implementation risk, including models and frameworks. An initial Google Scholar academic database such as Science Direct, Emerald and IEEE generated 70 records, of which five records were books. Of the 65 remaining articles, one was not in English, and 14 were removed. The remainder of the articles were analysed, of which four had proposed Risk management Frameworks. The studies in the theoretical framework,

such as in [29]'s study, conclude that the scientific foundation and theoretical work that has been made regarding risk assessment and management can misguide decision-makers. More studies need to be conducted about risk management, evaluation and mitigation. To explore and obtain a more robust scientific base about how risk is handled nowadays in an organisation. Thereby contribute to establishing a more developed scientific field of risk management [29]. In addition to the literature on risk implementation, a literature search was conducted on big data analytics types, factors influencing risk management in business intelligence projects and the influence of Owner managers in managing risk.

Research is beginning to emerge on the risks associated with big data analytics, investigating the barriers facing SMEs in adopting big data analytics and proposing ways to mitigate the barriers and exploit big data analytics opportunities [2]. Moreover, recommendations have been made for research to take a holistic approach to data analytics implementation, not only focusing on technology aspects [10]. Furthermore, calls have been made for research on managing big data analytics risk [8], explicitly identifying explicit data analytics risks and developing management processes at both the project and executive levels for mitigating or eliminating data analytics project risks [4].

The study collected data from SMEs. Hence, to reach all the study participants, a survey strategy was followed whereby a measuring instrument in the form of a questionnaire with closed-ended questions was used to collect data. Participants were chosen based on their knowledge and access to the necessary information, their experience and willingness to contribute relevant information to the study. The structural equation modelling was used to determine the factors that influence big data analytics implementation and the Best Worst Method was applied to prioritize the big data analytics implementation risks [17].

1.5 Findings and Discussions

Based on the literature review, a composite TOE Technology-Organization-Environment and Diffusion of Innovation theory are selected to develop the conceptual model of big data analytics implementation risks. As the use of Technology-Organization-Environment (TOE) and DOI Diffusion of Innovation theory (DOI) models may assist researchers in examining Information Technology use in Small and Medium Enterprises [9, 30]. For instance, the Diffusion of Innovation theory model focuses on the role of technological attributes as essential for Information Technology in organisations [31]. On the other hand, the Technology-Organization-Environment framework explains the internal and external factors that may affect firms' technology [32]. Integrating the Diffusion of Innovation theory model with the Technology-Organization-Environment model may lead to a comprehensive framework managing big data analytics implementation risks in Small and Medium Enterprises. A conceptual model drawing from the literature review discussion underpinned by TOE and DOI adopter categories is proposed and illustrated in the figure below.

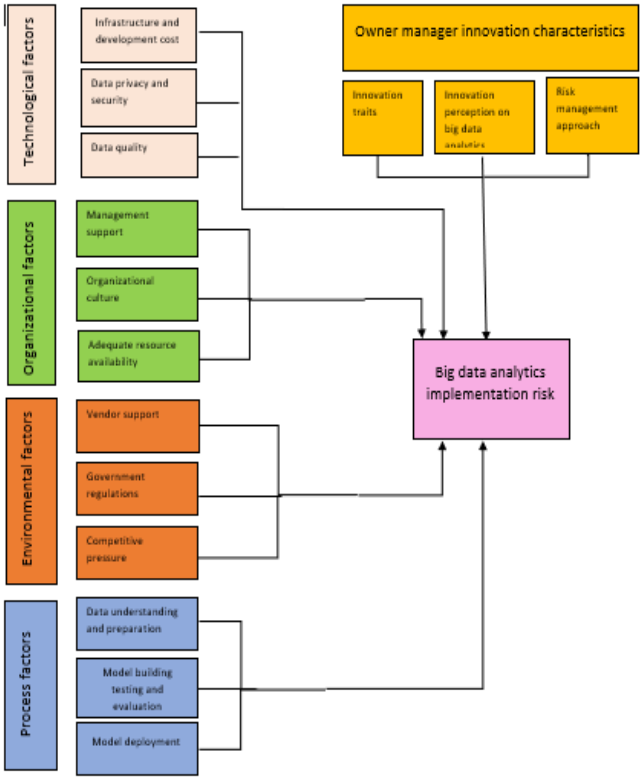

Fig. 2. The conceptual model

1.6 Conclusion

Despite several challenges in implementing big data analytics projects, big data analytics present untapped potential in Small and Medium Enterprises. The paper proposes a conceptual model for managing big data analytics implementation risk. The identified risks are underpinned by the TOE and DOI and categorised into five main areas: technological, organisational, environmental, process and owner-manager characteristics. Thus, the paper seeks to make a theoretical and practical contribution to managing big data analytics implementation risks and generate new insights that may be of value in supporting Small and Medium Enterprises' big data analytics implementation endeavours. Furthermore, the practical insights generated from the paper may be of value to Small and Medium Enterprises, big data analytics providers, and institutions providing Small and Medium Enterprises support services to Small and

Medium Enterprises, inclusive of governments. Small and Medium Enterprises and other organisations may use the proposed model in assessing big data analytics implementation risks and derive strategies for overcoming potential risks, subsequently reducing big data analytics implementation project failure rate. Thus enabling Small and Medium enterprises to tap into the opportunities presented by big data analytics in a dynamic and continuously changing business environment. Future research could empirically test the model and, in addition, rank the factors to provide valuable insights as to where Small and Medium Enterprises may focus efforts and scarce resources in managing big data analytics implementation risks. In addition, 2 future research could examine the identified risks and owner-manager characteristics in the context of different sectors.

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Rethinking Cars for Sustainable Mobility – Shared-Autonomous Vehicles and Circularity

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Abstract

Autonomous driving cars, underpinned by advancements in artificial intelligence, sensor technology, and the enhanced communication capability of 5G, are now poised to revolutionize transportation, promising significant improvements in safety, efficiency, and accessibility. However, the time for such a transition towards fully autonomous vehicles (AV) should coincide with the transition to Society 5.0, where cars are zero-emission vehicles and fully embedded into a circular economy (CE). This requires a radical change not only for the car industry but also for the car users, who are in the early transition from being car owners to car-users with automobiles becoming a more sustainable public mobility service. In this paper, we conduct a literature review about the state-of-the-art of autonomous driving and circular economy, as both cannot be established without substantial infrastructure enhancements for vehicle-to-everything communication and for building up more sustainable business models for the circular economy. We divide this journey into three different states where we provide a vision of new stakeholders and new business process models via the current state of its infancy, the middle state of its coexistence, and the target state of fully established Shared Autonomous Electric Vehicles (SAEV) and CE services. Given that such a radical change will undoubtedly face resistance, this transition scenario is analyzed using different aspects of power dynamics to show potential benefits and new business opportunities for the different stakeholders involved. In the final section, we show examples of different car manufacturers and how they see their current focus on new energy vehicles (NEV) and aspects of CE in their respective strategies.

Keywords: Autonomous Vehicles (AV), New Energy Vehicles (NEV), Shared Autonomous Electric Vehicles (SAEV), Shared Autonomous Mobility (SAM), circular economy (CE), process redesign, sustainable mobility

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1. Introduction

It is not an exaggeration to say that the automotive industry is being radically transformed. Routinely, there are articles in European newspapers indicating how the well-established European automotive market is facing a Chinese disruption (The Market, 2023). At the same time, European efforts toward a true transformational shift away from fossil fuels are dwarfed by the strong resistance from an industry that has to face valid accusations of complacency and underestimating the competition from abroad (Handelsblatt, 2023).

At the same time, as the World Economic Forum Report (WEF, 2020) states, a coalition of stakeholders from the automotive industry itself and beyond, compiled a report with several important key messages toward reaching a sustainable mobility system. They state that the automotive industry must reduce its carbon emissions and resource consumption by adopting circular economy principles, such as using renewable and recycled materials, extending vehicle lifetimes, improving vehicle utilization, and integrating with the energy grid. They estimate that circularity can reduce carbon emissions by up to 75% and resource consumption by up to 80% per passenger kilometers by 2030, compared to a standard 2020 internal combustion engine vehicle. However, they also mentioned that circularity requires a common framework and a systemic transformation to energy decarbonization, material circularity, lifetime optimization, and utilization improvement until reaching an optimized ecosystem by 2024.

However, the discussion, - and even the fears - of which country's cars will dominate European or even global streets is missing a fundamental point. Our new generation of drivers is very aware of car's contribution to global warming and is less and less interested in driving, let alone owning a vehicle that sits idle 90% of its time and costs money (The Guardian, 2023). Nonetheless, the reality is that this generation will also need to get from A to B. Hence, how do we design a mobility system that fits their wishes and needs and does not stretch the demand for virgin materials past the breaking point?

Moreover, as the world moves more to self-driving, autonomous vehicles on the road and in the air, there are questions we must ask. How do we design these vehicles to be fully modular and circular to avoid waste and increase their longevity? How do we ensure they provide mobility for as many people as possible in cities and rural areas? Autonomous Level 4 cars, meaning they are genuinely autonomous, are already circulating in cities like San Francisco, Austin or Shenzhen (Law, 2023) and the time to adjust our thinking about cars serving Society 5.0 has already started. Some of the key stakeholders involved in the transition to AV range from dedicated end-to-end software development platform providers such as NVIDIA to well-known pioneers of self-driving cars such as Tesla or Waymo from Google, up to the less recognized but the world's largest robotaxi service provider Apollo Go from Baidu, which operates in 30 cities with over 60 Mio km testing and more than 3 Mio commercial rides (Block, 2024).

However, can these companies also support material circularity and become part of reverse logistics, i.e., used materials are returned to the producer for a renewed sustainable mobility service? And if they are in movement all the time, as the human need for a break is eliminated, what kind of quality level must they fulfill to increase longevity? How can car manufacturers design vehicles that provide mobility for humans and goods and also continue to earn revenue in the process? What should be the global denominator that moves all infrastructure providers towards the same goal?

As these changes will affect all of society and its access to infrastructure, design change alone is not enough. Analysing the distribution of power is also crucial as it can significantly impact the outcome of projects. As described in Li et al. (2022), New Energy Vehicles (NEV), were put into China's National Key Science and Technology Industrialisation Projects in its 9th Five-Year Planning (FYP)

period, lasting from 1996 to 2000. It was thus the power of government that understood the need for a solution that both served the growing middle-class' desire for mobility and at the same time did not create a suffocating blanket of smog over cities.

Thus, in this paper, we will start with a literature review of the current state of autonomous driving and the circular economy and the required infrastructure changes. We divide this transition process towards fully circular and autonomous mobility services into three scenarios: Scenario 1 is the short-term, representing current ***infancy*** of AV and CE, with linear economy; Scenario 2 is the mid-term, representing the ***coexistence*** of Human Driven Vehicles (HDV) and fully AD vehicles with the linear and circular economy and; Scenario 3 being the long-term, representing the ***established*** *AD, with circular economy,* including all supportive infrastructure and smart city operational facilities. After this journey, we will provide insights into the current state of thinking of the car manufacturing companies themselves, then consider insights from this study of rethinking cars for more circular, sustainable mobility and then finish with some compelling evidence that CE and AD combined can lead us to a more sustainable future.

2. Literature Review

The literature review is divided into three topics that are necessary building blocks for the design and analysis of the different implementation steps of AV and CE namely: shared, electric AV; the circular economy, and; AV infrastructure.

2.1 Shared-Electric AV

Currently, there is justifiably a plethora of contemporary literature on AV as they are now seen as the future of mobility and thus have a potential consequential disruptive impact not only on the environment but also on society and the economy (Williams et. al. 2020). The positive impacts of AV range from safety improvements, increased accessibility by the elderly and disabled people, more effortless driving, with less congestion and environmental impact. On the other hand, AV may have adverse impacts, including loss of driving jobs leading to shifts in the labour force and behavioral uncertainties regarding how consumers will consider their willingness to travel (Onat et.al., 2023). AV will also have a considerable impact on the Original Equipment Manufacturers (OEMs) with the most important traditional key components such as the engine, transmission, and chassis being replaced by many new key components such as 5G communication and sensor technology. In addition, the required software engineering/machine learning processes for continuous updates and deployment of machine learning models will become key skills for New Energy Vehicles (NEV) and also Shared Autonomous Electric Vehicles (SAEV) manufacturers.

Moreover, SAEVs have the potential to play a vital role in terms of energy management. Iacobucci et. al. (2019) describe a scenario with SAEV used as a Virtual Power Plant (VPP) or a microgrid with intermittent renewable energy. The model simulates aggregate storage availability from vehicles based on transport patterns and optimizes charging. The case refers to a grid-connected VPP with rooftop solar and the case of an isolated microgrid with solar, wind, and dispatchable generation. The results show that SAEVs offer significantly lower costs compared to privately-owned vehicles. SAEV can also substantially decrease the total number of cars needed worldwide. They after all will be continuously operating on the road instead of standing still in a public or private garage which is the situation for more than 95% of the currently owned private cars. As Duarte (2018) points out, cars can and will be redesigned to be suitable for working, sleeping or socializing and be much enhanced in terms of comfort and functionality.

Implications of autonomous driving cars to the infrastructure are also quite diverse and raise challenges ranging from harmonization of traffic signs to a review of common design patterns addressing new ways of collaboration in a city (Mihalj et al., 2022). However, SAEV also has the potential to change life as we know it in urban areas and we would like to point out the following list of important facts which support our three transition scenarios in Chapter 4. SAEV will: (a) provide accessible mobility services to the home for all citizens; (b) require fewer parking spaces that can be reused for pedestrians or bikes; (c) serve as energy storage like hydroelectric power plants; (d) be much more complex with respect to software, sensors, ML models and; (e) allow for dramatic new designs.

2.2 Circular Economy and SA Vehicles

What is the Circular Economy? The circular economy is easily explained: it is simply a world without waste. According to Ellen MacArthur Foundation (2024), it aims to design out waste and pollution, keep products and materials in use for as long as possible, and regenerate natural systems. This definition avoids the confusion with the term "Recycling Economy" that many mistakenly still put on the same footing as the circular economy. Because waste management companies are actively affected by this transformational shift, Kirchherr et al. (2017), found 114 varying definitions of the circular economy. Despite this, there is consensus that continuing with the linear model of producing waste and hoping that better waste management and recycling will solve humanity's problems is not enough. As the definition states, the core concept of the circular economy is the requirement to design out waste. It is no surprise that certain industries are embracing circularity faster than others, as presently product and supply chain complexity creates numerous obstacles. As we will illustrate later, power structures can help the circular transition. To illustrate, Rentizelas (2022) states that regulatory initiatives propel car manufacturers toward a circular economy paradigm that incorporates reuse, remanufacturing, and recycling processes. And, Halia (2023) conducted a qualitative descriptive analysis of the top 10 automotive companies on the Global Fortune 500 List to assess their respective levels of circularity.

Why Do We Must Start with Design? As with all life in nature, design refers to eliminating the concept of waste all altogether by reusing everything where all waste becomes nutrients for subsequent growth (Baumgart & McDonough, 2009). As our world is buried in waste, a totally different approach to how we make, use and dispose of products and services is required. The primary responsibility lies primarily in the initial design phase because once a product specification is decided, it enters the production phase and then only minor changes become possible (Nasr, 2016). Decisions made at the design phase influences 75% of the products' economic cost and also 75% of its social and environmental impacts. It is not surprising then that design now plays an increasingly crucial role in the production process. However, this new imperative is not just to create products with extended life cycles, but also to revert to designs where parts can be repaired and materials brought back at the end of usage. This requires a radical shift in thinking about how our monolithic products can have a more modular design such as following a LEGO metaphor. As separate parts have different longevity levels, a modular design allows the repair and/or replacement of broken parts without discarding the whole product.

However, based on observations of NEV in China, they are not yet convincing all about their longevity. Yes, they could become LEGO bricks, which can be adapted for individual mobility needs and used as parts of a shared mobility infrastructure for individuals and organizations. AV in principle could fulfil this function since they can be dislocated and used, wherever needed. Hence, this idea begs a question: How should AV be designed to serve as a mobility infrastructure in urban and rural areas and also leave no waste behind at the end of their lifecycles? To design out waste, companies must close

their own product loops and bring their end-of-lifecycle products back to be used as raw materials once again. The captivating question that has been occupying our minds is: can autonomous vehicles be designed to transport passengers and also serve as a reverse logistics infrastructure for companies? If yes, how do they need to be re-designed?

Why is Circularity Itself Not Enough? Thus far, we have addressed the issue of how consumers could be open to replacing their combustion engine vehicles with electric cars. However, as Figure 1 below shows, that mindset opens a pandora box of new challenges as NEVs actually require significantly more virgin resources. Hence, only a smaller total number of vehicles and a durable, modular (LEGO style) SAV can offer benefits of improved mobility and also reduce the pressure on virgin resources. In the design of SAVs, there are two elements to consider with completely different lifecycles: the vehicle body itself and also its battery. Both have to be designed for longevity and there are several reasons for this requirement: a) in an established system, companies can reuse these materials as raw materials, and; b) this reuse will help companies bridge their raw material needs as the current demand for certain metals is inevitably going to increase as the investment in new extraction sites might not meet the speed of demand and; c) the current pollution and landfill situation does not offer any space for more waste materials.

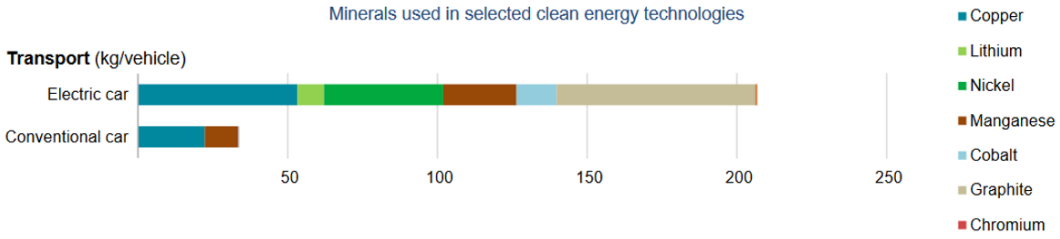

Fig. 1: Demand for Minerals, Source: International Energy Agency (IAE, 2021)

Without addressing these realities both the vehicle and the battery will otherwise become waste. Currently, different NEV producers are working on disparate battery solutions. However, these efforts rarely consider circularity in the design phase (Masiero et al., 2016). This will change radically in the upcoming years due to resource shortages as the NEV industry is competing in the renewables sector for the exact same resources.

Another social concern to consider is the commodity market. The production of crucial resources for NEV is geographically even more concentrated than oil and gas (International Energy Agency, 2021). For example, the world's major exporter of cobalt is the Democratic Republic of Congo (DRC) with 70% of global reserves and 51% of world production (cobaltinstitute.org, 2023). Yet, details about human rights abuse and environmental issues in the DRC have been widely reported. Moreover, 98% of all the cobalt that is mined as a by-product as it does not have its own ore and depends on copper and nickel mining demand. Some countries like Indonesia are curbing their exports of mineral ores in order to spur job creations at home. These regulations will heavily influence the price of the commodity (The Straits Times, 2023).

2.3 AV Infrastructure

AV infrastructure has received little attention thus far since many stakeholders have initially focused their attention on issues related to AV (e.g. safety). More focus on AV infrastructure requirements to promote Shared Autonomous Mobility (SAM) will soon be needed. For example, there are no established guidelines regarding adequate road infrastructure to support AV operation in our diverse

urban environments. However, it is envisioned that some infrastructure changes will inevitably be implemented during AV pilots, additional infrastructure to suit mixed traffic (AV and HDV), and finally, an infrastructure that can support a complete transition to automation.

For regular AV requirements, there are typically five levels of automation. We are focussing on level 4, where AVs are equipped with vehicle-to-everything (V2X) technologies that will enable genuinely autonomous driving. According to (Manivasakan et al., 2021) the required infrastructure includes the following: (1) digital infrastructure; (2) physical infrastructure; (3) usage, human-machine interface, accessibility, and vehicle aspects; and (4) cybersecurity, data management, and privacy. For electric AV, significant additional infrastructure will be needed, including:

Charging Stations. A robust network of public charging stations is required. These stations should be strategically placed in urban areas, on highways, and in other high-traffic locations to ensure convenient access for NEV owners. In addition, drivers will need to access overnight charging capabilities at their homes or apartments.

Clean Power Supply. Sufficient clean power generation to support these vehicles is also needed. Using renewable energy sources (e.g. solar and wind) is crucial in sustainably providing electricity for charging stations.

The NEV infrastructure demands include personal cars, utility vehicles, delivery trucks, public transit, and commercial fleets. In addition, municipalities must develop charging standards into their permitting processes, invest in the essential electrical infrastructure, and develop methods and regulations for retrofitting existing buildings and parking facilities.

2.4 Circular Economy Infrastructure

The above-mentioned infrastructure enables a smooth operation of NEV and, consequently, SAV, but does not address circularity. Current supply chains are highly efficient but operate only as one-way highways. Moving forward, existing infrastructure must be reconfigured, as well as, new ones constructed (Nogueira, et al., 2020), in order to reach the material circularity that the European car makers demand. The industry's resources are often mined in a faraway part of the world, processed somewhere else, formed into products elsewhere and then sold in yet another country. Hence, regaining materials from end users can pose a significant challenge for producers. For this reason, in this paper, we look at the circular economy infrastructure from two sides. Firstly, what kind of infrastructure is necessary for SAV producers to get their materials back at the end of the life cycle? And, secondly, can SAV include a designated transportation area that can support the circular infrastructure of other companies? To access secondary materials, companies will need to design their own reverse logistics, or they can access the so-called secondary markets. As Goovaerts & Verbeek (2018) rightfully argue, *"...competitiveness of a business today is not solely dependent on its own performance but on the value-creating systems within which it operates*." However, the first approach might require a large upfront investment, which might not be welcomed by all stakeholders, especially investors and shareholders. Companies are prone to show a lukewarm investment interest and only comprehensive regulatory pressure can exhibit enough power and impact the companies' cost priorities in order to accelerate these investments. The second approach requires well-developed secondary markets where the value of used materials is well-established and traded. Companies can purchase these materials like any other resource and use them for their production. These markets can only be successful if ultimately the cost of secondary materials is lower than virgin materials. As a consequence, these markets can only thrive if their extraction and their path to the trading hub are not too costly. Under the assumption that these markets develop in major production hubs, which are likely be urban centres as they are linked with the

smart city approach that aims to increase sustainability in urban areas, SAV can support these local markets by delivering secondary materials to assigned storage spaces. From there, it can reach trading spaces. However, this assumption depends entirely on municipal leadership, their commitment to circular economy and their willingness to co-finance the supporting infrastructure and the system dynamics within their constituencies.

3. System Dynamics and New Design Considerations

Considering the intricate nature of changes within each of these topics and their interconnectedness, any radical transformation required to achieve the objectives of the envisioned sustainable mobility scenario - one that challenges existing mindsets - will undoubtedly face considerable resistance. Avelino (2021) examines power dynamics within the context of social change and invites us to formulate empirical questions on the relationships between power and processes of social change and innovation. She offers seven prevailing points of contestation in academic debates on power, which we use to reveal important insights and potential solutions for paving the way for rethinking of cars for sustainable mobility.

Power 'over' versus power 'to': This refers to the ability of an actor to control, influence, or dominate *'over'* others versus an organization or individuals which also may also have the ability *'to'* act. While traditional car manufacturers have historically held significant power *over* the entire automotive value chain from production, distribution to pricing, new NEV startups such as Tesla have disrupted the industry by making changes *to* established norms. As mentioned earlier, in China, the success of NEV goes back to China's National Key Science and Technology Industrialisation Projects in its 9th Five-Year Planning (FYP) period, lasting from 1996 to 2000. In the West, governments and regulatory bodies exert power over the industry by setting emission standards, safety regulations, and taxation policies.

Centered vs. Diffused Power: Concerning power there is also a significant difference in how China and the Western World see power. The Central Government in China makes decisions based on a single-minded strategy, while in Europe multiple stakeholders need to agree to a solution before new initiatives can be implemented. As consumers become more informed and more environmentally conscious, their growing demand for electric and sustainable vehicles will empower them to shape the industry. Shared mobility services (e.g., ride-hailing, car-sharing) also give individuals the *"power to"* access transportation without car ownership. In effect, these platforms democratize mobility.

Consensual vs. Conflictual*:* The sheer number (and also the size) of cars today clearly contributes to congestion, pollution, and resource depletion. However, car manufacturers are nonetheless maximizing production and sales to generate revenue and profits and thus may resist reducing production due to their short-term financial interests. After all, lower production could impact revenue, employment, and market share. This could then lead to conflicts related to environmental impact, urban planning, and infrastructure strain. However, as shared mobility, ride-hailing, and carpooling continue to become a valid alternative to private car ownership, car manufacturers could invest more in shared mobility platforms, creating win-win scenarios for themselves and their customers.

Constraining vs. Enabling*:* The development of NEV can be seen as an exercise of innovative power *'to'* new car manufacturers and consumers who are creating new resources and challenging the existing structures of our fossil fuel dependency. However, NEVs also depend on the availability of electricity, charging infrastructure, and especially battery materials, which can constrain their acceptance and impact. However, it is clear that autonomous driving can enhance efficiency and safety and their self-driving features can be used to optimize energy consumption, reduce traffic congestion,

and improve overall transportation efficiency. Despite these assets, the development of a reliable SAV infrastructure is complex and resource-intensive. Potential safety concerns, regulatory hurdles, and ultimately public acceptance are constraining factors.

***Quantity vs. Quality*:** By designing cars that are more durable, modular, repairable, and recyclable, the car industry can extend the lifecycle of cars and reduce maintenance costs. The circular economy can change the way power is exercised and distributed in the car industry by creating new opportunities for collaboration, innovation, and transformation. As long as the car manufacturers remain the primary owners of their own cars within the Product-as-a-service business model, increasing the quality of cars will be in their own interest. And, as owners of the batteries, they can also harness the collective charging and recharging capacity of their entire vehicle fleet and be in a position to offer energy supply services akin to the vital role played by water reservoirs in a country.

Empowerment vs. disempowerment: Governments and regulations can either enable or constrain the innovation and transformation of any economic sector. Regulators can empower car manufacturers and consumers by providing incentives, subsidies, infrastructure, and information for the adoption of NEV. Insurance companies can be empowered by collaborating with AV mobility service providers to offer bundled insurance packages.

Power = knowledge vs. power ≠ knowledge: Avelino (2021) also refers to the debate on whether power and knowledge are inseparable or distinct phenomena. As Society 5.0, we have access to a lot of information but often lack the ability, or especially the authority, to act on it appropriately. Humanity should favor both the common good CE principles and shared AV mobility services over the individual power prestige of car ownership with its less expensive but environmentally unfriendly products.

4. Scenarios for AV & CE Implementation

To better visualize the transition from the current state of car manufacturers and private and corporate car owners to the future state of fully autonomous vehicles and circular economy services, we suggest viewing snapshots of potential business processes that characterize the different stakeholders, their interactions, and the available infrastructure with the help of three business process models for short, mid, and long-term scenarios.

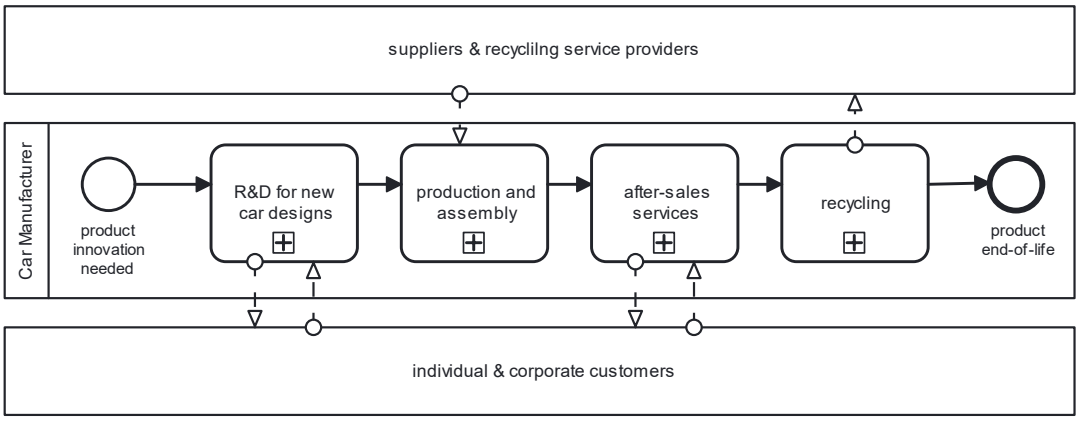

Fig. 2. Short-term scenario: current infancy of AV and CE

Short-Term Scenario: Current Infancy of AV and CE: The current life cycle thinking of cars is mainly centred around three stakeholders, which is visualized in Figure 2. R&D of the car manufacturers has been mainly designed with individual or corporate customers in mind who typically own their cars for up to a decade or more. And, in many countries and cultures, the purchase by these customers also serves as a status symbol with luxury brands and high-performance vehicles being associated with wealth, power, and prestige. Indeed, being able to drive one's own car is one of the important prerequisites for business life. |In addition, this status quo also provides a considerable market for driving instructors and plays a crucial role in traffic safety and therefore intrinsically involves the entire insurance business. Given the constant global trend of increasing vehicle production over the past two decades with 89.8 Mio produced in 2023 (S&P Global, 2024) and the total number of now about 1.4 billion cars worldwide (Hedges & Company, 2023), demands to improve environmental compliance are growing. Hence, due to this pressure coupled with rising fuel costs, the R&D of manufacturers is placing a growing emphasis on energy efficiency, leading to an overall increase in efficiency of around 6% since 2021. However, the new demand of customers towards more innovatively sustainable cars can be supported by new tools (Bauer, C., 2020) that can help meet not only CO_2 emissions but also other further relevant environmental indicators that are factored into car buying decisions. Collectively, this has the potential to steer the life cycle of cars towards greater sustainability. And as illustrated earlier, the increased materials need for NEV accentuate this urgency for even more sustainability.

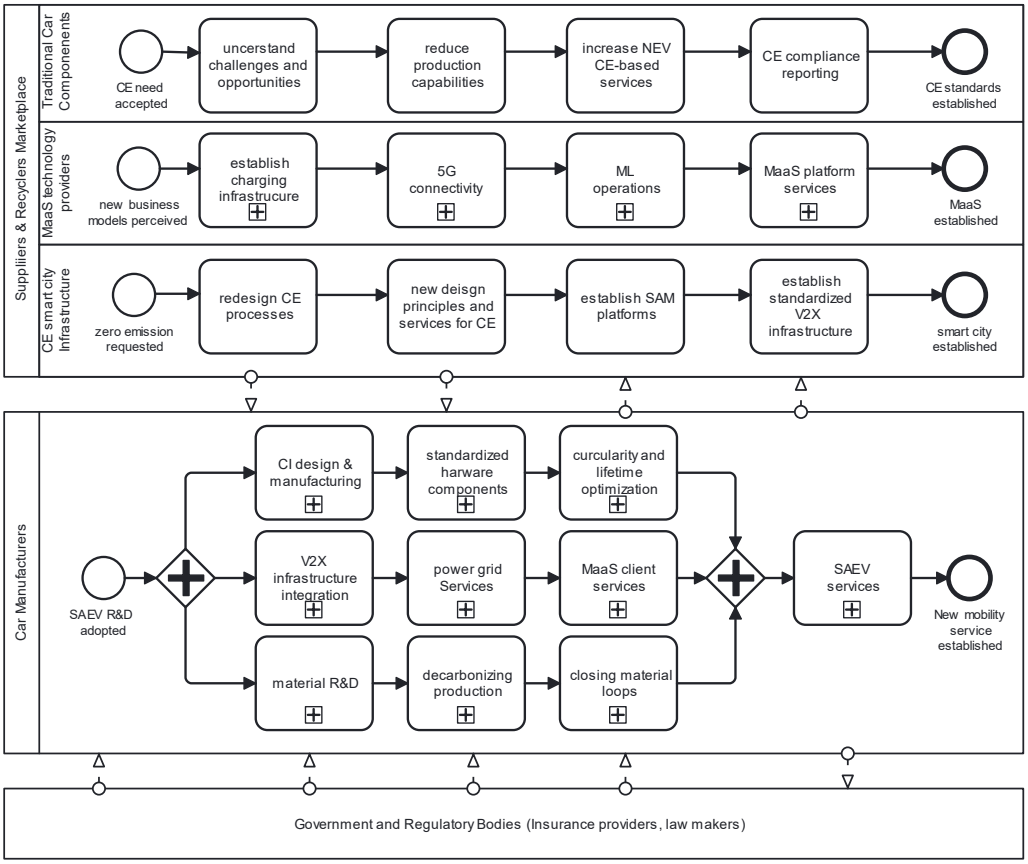

Fig. 3. Mid-term Scenario: Coexistence of AV and HDV

Mid-Term Scenario: Coexistence of AV and HDV: This scenario is characterized by having around 50% of the market by Shared Autonomous Electric Vehicles (SAEV) in Level 4 with the remaining 50% being Human Driven Vehicles (HDV). Many highways now have dedicated lanes for AV, which all move at the same constant speed, with less fuel consumption and almost no congestion. Most car manufacturers have adopted to new SAEV Research and Development (R&D) approaches, which are represented in Figure 3. As the majority of the key components of modern vehicles are using highly sophisticated software, increasingly communications such as Machine Learning models and contemporary software engineering best practices will have to be incorporated into new car designs.

Long-term Scenario: fully established SAEV and CE: This long-term scenario (see Figure 4 below) shows the potential for establishing new services and new business processes between some of the new, emerging stakeholders.

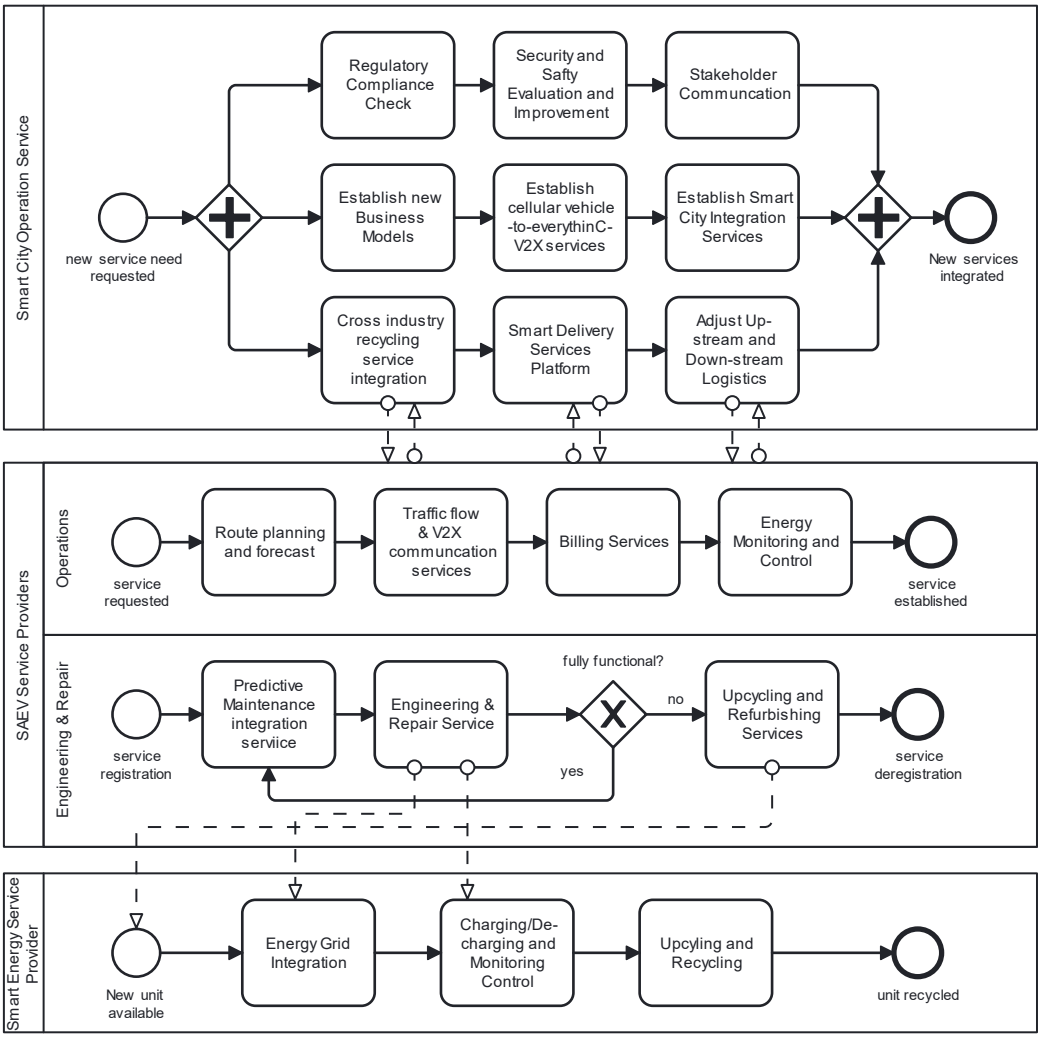

Fig. 4. Long-term Scenario: fully established SAEV and CE

Envisioning the scenario of fully-established AV and CE services, such as addressed by Quentin et. al (2023), who explore how AV can contribute to the transition towards the CE in the Rhine-Main Region in Germany has started already. From their albeit local perspective, they point out the important role of transport planning practices, including shared mobility services and the redistribution of road space and a broader view on transport development and demand management. On the other hand, there are many articles, that envision the role of AV in the CE, and they often discuss their potential to reduce waste and resource consumption by reusing, repairing, and recycling materials and products (Willams et.al, 2020).

Discussing further the long-term scenario of SAEV and CE, cities are establishing their Smart City Operation Services which include new governance aspects, new business models around the V2X and new cross-industry up and down-stream logistics which are necessary for the local support of the CE. These three different kinds of activities are visualized as three parallel lines and allocated to the Smart City Operation Services pool as can be seen in Figure 4. Car manufacturers have undeniably implemented their transition to smart SAEV mobility service providers. They not only drive the operation of the transportation services, which needs to be integrated with the Smart City Operation Services, but have also established CE principles, which are in part inspired by the aforementioned LEGO metaphor. Their entire fleet is under AI-based predictive maintenance observation where each of the parts can be repaired or upgraded on demand to the new requirements of the Smart City Operation Service. All cars and therefore all components need to be designed for much more robustness and thus longer operational lifetimes.

This scenario also models the dependency of the SAEV mobility service providers to other potential independent service providers such as battery manufacturers, who now also offer their batteries as services. As mentioned in the beginning, cars are increasingly complex ultimately and all LEGO-type components will also be provided as a service. In case the of batteries, they are also constantly monitored, charged, recharged and thus integrated into the energy grid of the city. Once the end of life for a car has been reached, its batteries could still be upcycled as energy storage for different purposes where the degradation of their function could still be tolerated.

5. Examples from Car Manufacturers

As mentioned previously, the transition towards electrification, autonomous driving, and circular economy as part of the sustainability strategy to rethink cars for greater sustainable mobility has become a focal point for global car manufacturers. They are strategically and increasingly aligning their product portfolios to realize this paradigm shift towards sustainable and technologically advanced practices, mainly to achieve carbon reduction targets but also not to lose market shares to innovative competition, especially from China.

It must be understood that electrification now stands as a cornerstone for reducing carbon emissions and our dependence on fossil fuels. Car manufacturers such as BYD and Tesla already offer an electric-only product portfolio. Other car manufacturers such as the BMW Group, the Mercedes-Benz Group, Volkswagen, or the Volvo Car Corporation are transforming their product portfolio into an electrified assortment, with each of them defining their individual targets. For instance, the Volvo Car Corporation wants to transform into a fully electric car company by 2030 by offering electronic cars only (Volvo Fully Electric, 2024). The Mercedes-Benz Group is preparing to offer electric-only cars by the end of this decade if market conditions allow (Mercedes-Benz, 2021). Table 1 provides more comprehensive targets and statements by car manufacturers regarding electrification. Whereas electrification is quite concrete, and this realization is already (at least partly) in place, the integration of autonomous driving

Table 1. Targets and statements regarding electrification and circular economy by global car manufacturers

Car manufacturer	Electrification	Circular Economy	Sources
BMW Group	"Electric mobility is among the major topics driving the ongoing transformation in the automotive industry. […] Our electrified vehicles are playing a major role in reducing fleet emissions and thus achieving our ambitious strategic carbon reduction targets."	"[…] the BMW Group has defined circularity as a strategic focus area. Our aim is to gradually bring the company closer to the ideal of the circular economy. From raw materials to recycling, we have the entire value chain in our sights"	BMW Group Electromobility, 2024; BMW Group Circular Economy and Circularity, 2024
BYD	BYD is the world's first carmaker to stop the production of fossil-fueled vehicles.	"BYD advocates the development of a circular economy, actively explores ways to improve the resource utilization and reduces the total use of packaging materials."	Times, 2022; BYD, 2022
Mercedes-Benz Group	"Mercedes-Benz is getting ready to go all-electric by the end of the decade, where market conditions allow."	"The overarching goal of the so-called circular economy is to keep as much as possible of the raw materials used in circulation."	Mercedes-Benz, 2021; Mercedes-Benz, 2024b
Volkswagen	"The battery is a key component in an electric vehicle, and an important cost factor. […] At the heart of this strategy is the new unified cell, which […] will be used in up to 80% of Group models by 2030"	"Volkswagen has anchored circular economy as a focus topic […]. Cross-divisional and cross-brand working structures have been developed at the Group level for managing the topics to be developed."	Volkswagen Group Strategy, 2024; Volkswagen Group Sustainability Report, 2023
Volvo Car Corporation	"Fully electric by 2030. […] by then we want all our new cars to be pure electric."	"…we're aiming towards becoming a circular business by 2040 – minimizing our use of primary resources"	Volvo Fully Electric, 2024; Volvo Sustainability, 2024

technology is currently being tested and is seen to be revolutionizing the automotive landscape, including all the underlying business models and the customer's mobility experience (e.g. Mercedes-Benz, 2024a, Volkswagen Group Strategy, 2024).

With respect to CE, targets and ambitions are, to a certain extent, already incorporated into corporate strategies and budgets and mostly reported in corporate, social responsibility (CSR) reports. However, huge differences among the car manufacturers concerning the extent of their ambitions and their commitment to these measures can be observed. Also, some car manufacturers limit their circular economy practices to only selected vehicle components or focus only on some minor aspects, e.g. on packaging materials. To illustrate, the BMW Group distinguishes the circular economy into four

different aspects. Firstly there is the design and development-enabling recycling at the end-of-life of the vehicle. Secondly, the supply chain and production approaches aim to increase the usage of secondary materials. Thirdly, there is a vehicle use phase focussing on the usage of recycled paper as a kind of resource-efficient packaging in the aftermarket business, as well as, on bringing components back into the re-use cycle. Fourthly, and finally, the end-of-life phase considers remanufacturing and recycling as a source of secondary raw materials (BMW Group Circular Economy and Circularity, 2024). The following table provides greater insights into the respective electrification and circular economy ambitions of five major global car manufacturers. The Volvo Car Corporation adds even more concrete measures and key performance indicators to its ambitions. Currently, 36 different component groups (such as engines, gearboxes, or clutches) are remanufactured, aiming at 35% recycled content in new car models by 2030 (Volvo Sustainability, 2024). On the other hand, the BYD CSR Report 2022 informs us that, under the section of green procurement and circular development, BYD is actively exploring ways to reduce resource utilization, focusing on the total use of packaging materials (BYD, 2022). Observing these declarations in Table 1, it is fair to conclude that car manufacturers are currently in the infancy phase of AV and CE and there is a long way to go to realize full integration of SAEV and CE.

6. Conclusions and Outlook

This paper addressing the subject of rethinking cars for more sustainable mobility has presented a literature review of the current state of autonomous driving and circular economy and their necessary infrastructure, presented three scenarios (short, mid, and long term) regarding the transition process towards fully-circular and autonomous mobility services, and provided insights into the global car manufacturers' targets for electrification and the circular economy. Based on this study, the following comments are offered:

***Redesign**:* The motivation for this article arose from the fact that CE should be incorporated in all the lifecycle stages of AV, including planning, design, operation, maintenance, and disposal. In particular, great opportunities exist to incorporate CE in AV design. Thus, the new imperative is not only to create products with extended life cycles but also to rely on designs where parts can be repaired and brought back to the manufacturer at the end of usage.

***OEM and the Circular Economy**:* A concise analysis of industry practices among global car Original Equipment Manufacturers (OEM) has been presented. It is evident that the CE concept is not yet nor nearly fully realized within current business frameworks. The explicit and mere mention of packaging material reduction in OEMs' CSR reports as a means to achieve CE goals highlights the urgent need for increased attention from researchers, industry practitioners, regulators and ultimately consumers. This will present opportunities for integrating CE practices into evolving business models and the transformation within the automotive industry. However, the current literature review is based on only a few OEMs and does not include other stakeholders from the automotive ecosystem. This should be investigated in depth in further studies.

***Infrastructure**:* The literature review presented some deeper insights into different aspects of autonomous driving, specific thoughts about the circular economy, and the related AD and CE infrastructures aspects for both. This review also showed that AD and CE are not isolated topics as both require substantial additional infrastructure to be built.

***Scenarios**:* The presented scenarios on the transition from the current state to fully autonomous vehicles with a circular economy reflect the experience of the authors - Western researchers based in Europe and

Canada - who have also had extensive experience working for Chinese organizations and/or living in China. We are aware that the elements of the presented scenarios may appear simplistic, given the complexity of the two systems involved (AD and CE) and the related technological, economic, and social considerations. Nonetheless, we believe the presented relationships between these two emerging systems are reasonable and provide evidence that CE and AD can lead us to rethink how we make cars to achieve a more sustainable mobility future.

Limitations: As most AVs are electric and, as such, require energy for not only charging but also for building the associated extensive IT infrastructure, future research should assess and evaluate whether the increased levels of energy consumption will offset environmental benefits. In addition, this paper does not factor in the time element or the possible adoption of Product-as-a-Service practices. That is, even if car producers design and produce truly circular AVs now, it will take at least ten years until that vehicle is possibly returned to be used as a secondary raw material.

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Critical Success Factors for Implementing Empathic Design in Agile Teams

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Abstract. Agile software teams focus on achieving a working product as fast as possible. This, however, is often accomplished to the detriment of user-centered design principles. Although several tools have been developed that enable agile teams to implement empathic designs in their projects, literature indicates that user experience designers struggle to influence software development teams, while developers find it challenging to collaborate with designers and remaining agile. This study serves to identify critical success factors (CSF) for the implementation of empathic design in agile software development teams. An interpretive case study was performed on an agile software development team to identify these CSF for implementing empathic design. This study found that client buy in, and the implementation of a hybrid agile method are important to the success of implementing empathic design.

Keywords: HCI, Usability, User-centered design, Agile, Empathic design, Critical success factors

1 Introduction

The core of agile software development is its ability to respond fast to any changes in the software development environment. Developers that use agile development methodologies seek to gain knowledge from the existence of the product, thus the need to fail fast so that faults in the product can be identified and improved upon [1]. Agile software development focuses more on producing functional software rather than on documentation and processes [1-4].

Praised for its lightweight, fast-moving pace, agile teams produced software in iterative releases as opposed to publishing it once the entire system was fully functional [1-3, 5]. Each mini release needs to be a stable version of the software where more features can be built. These mini releases are usually done in short sprint cycles during which the development team focuses on releasing new features in each sprint [1, 3].

Unfortunately, end users are often not part of the development process or are involved in unrealistic and unsustainable ways such as acting as “site end users” or end-user representatives [4, 6].

Expected end users, or users that fall within the same demographic as the expected end users can be interviewed in focus groups or individually. During these sessions

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the UX researcher may ask the participants to perform card sorting exercises, participatory design exercises and usability tests on any existing software. Rigorous user-centred methods of field investigation can be time consuming, a stark contrast to the fast paced, quick release standards of the agile process [4, 7].

User-centred design (UCD) is a design philosophy that emphasises the user's needs throughout the development process [8]. The core principle involves that the intended end user is consulted continuously throughout the product life cycle, using the above-mentioned user-centred methods of field investigation. UX designers use UCD, aiming to identify and document as much of the requirements beforehand as possible, allowing for a holistic view of the environment in which the product functions so that a useful solution can be created [9]. Once a product has been released, field research is conducted by observing how users interact with the product, whereafter changes are made to increase the accessibility of the product. Alterations to the design of the product, based on the feedback received from conducting field research, are introduced in iterative stage [4, 8], and design translations must be facilitated between designers and developers to ensure that developers understand the reasons for the alterations.

Several techniques have been created that help to facilitate empathy during the design process, such as user-centred design, human-centred design, co-design (Co-D) and participatory design (PD) [10]. These design techniques enable empathic design by allowing the designer to take the user's perspective and practice cognitive empathy. Designers are encouraged to envision the user's thoughts, feelings, and needs to identify the requirements of the software solutions [10].

Although these techniques are well established for designers, there seems to be a lack of methods for enhancing empathy towards the end user in the workplace in general [11]. The goal of design is to create a useful product for the intended user; the extent of the design's success can only be proven by the users themselves [11, 12]. The use of design thinking allows for creating a technically viable software project that meets the user's overall expectation while remaining economically feasible to execute [13]. This paper asks the main research question: What are the Critical Success Factors for implementing empathic design in an agile software development environment?

In section 2, a literature review on software methodologies, user experience design, empathic design and aligning empathic design with agile are discussed. Section 3 the research methodology followed in this study is described followed by the research findings and conclusion in Sections 4 and 5 respectively.

2 Literature review

2.1 Software Development Methodologies

There are several Software Development Life Cycle (SDLC) models that are used to manage the phases of development such as planning, analysis and implementation. Two of the SDLC models that are relevant to this research paper are the Waterfall and Agile methodologies.

The Waterfall method consists of the sequential development of software, where the output of a previous phase will serve as input for future phases [14-16]. Each phase of the development process must be completed before the next phase of development can begin. The Waterfall method is the most traditional project management methodology that allows team members to work linearly towards an end-goal. Every member of the team has a set goal to achieve; and the estimations and expectations do not change over time [14]. Testing is only carried out once the software has been fully developed, which causes defects to be detected very late in the software life cycle [15].

Agile software methodologies were developed to respond quickly to the ever-changing environment in which software is created [2, 14, 17-19]. Although agile is highly compatible with user-centred design techniques, the focus on creating usable products usually diminishes throughout the project timeline, and the focus is shifted towards producing working versions of the product as quickly as possible [2, 3, 8, 20, 21]. The Agile methodology's iterative and incremental approach allows for effective system requirements management and aligning the product with customer needs [19, 21, 22].

Faced with the benefits and challenges of both agile and the waterfall methodology, software teams have recently started implementing a hybrid agile methodology [21, 23, 24]. Hybrid agile promotes the combination of plan-based development models such as the waterfall methodology, with the agile software development methodology. This method provides a range of benefits including improved project quality, faster time to market and better resource allocation accuracy due to better workload estimation [21, 23].

2.2 User experience (UX) and User-Centred design (UCD)

User experience is defined in ISO 9241-210 as 'a person's perceptions and responses that result from the use or anticipated use of a product, system or service' [18]. Hinderks, et al. [18] conclude that the user experience is thus a holistic concept that encompasses the physical, emotional, and cognitive reactions a user has when interacting with a product. This experience can happen before, during or after the use of the product.

User-centeredness or user-centred design is a design practice where designers follow a process of focusing on usability, user goals and desires throughout the development stages of the software, as well as later during the system life cycle [2, 25, 26]. User-centred design is defined as an approach for developing interactive systems to make a product usable and useful, with a particular focus on the user to understand their experiences and requirements [27]. It highlights the need to understand the human factors and usability techniques when developing software.

User experience (UX) designers fulfil a range of roles in the product development and design process. Their influence ranges from conducting user research, creating prototypes, designing user interfaces, and even specialising in how users interact with company copy (content created by a company to increase brand awareness that is meant to persuade customers to act). UX designers usually practice UCD as it is the

most effective way to design products that satisfy all the user's needs while also being delightful to use [28]. UX designers intend to empathise with users in various ways, such as through user interviews, observations, and personas. Personas are fictional characters that embody the characteristics and traits of the intended end user that allows designers to design products that are more aligned with the user's goals and needs [25].

2.3 Emphatic Design

Empathy is widely researched in many fields, each focusing on different aspects of the broader term. Empathy is defined as "the ability to understand the feeling of others" [29]. Empathy aims to construct a mutual understanding of how a person perceives an experience [11]. Empathy has a critical impact on design thinking [43]. Kouprie and Visser [30] argue that by using empathy as a core part of the design process, the designer is moved away from solving rational issues and focuses more on solving for personal experience and user context. Perspective taking is a skill that designers need to enhance to create delightful, impactful and valuable products [10, 31]. Empathy should become part of an organisation's knowledge construction as empathetic insights can be gained from interactions with people regarding the technology used, knowledge about user needs, user language, cultural symbols etc. Designers and developers should learn to adjust their own perspectives in favour of the perspective of the user [11, 26].

Designers use different tools to increase empathy with the user while designing. These tools include the use of personas, which allow designers to empathise with fictional characters, similar to how a reader would empathise with characters in a storybook [25].

2.4 Aligning User centred design and Software development

Due to the functioning of each role, designers and developers look at problems from different perspectives. UCD aims to produce the whole user experience while developers divide the work into smaller releases [22]. UCD works with a more holistic view, whereas developers break down problems into modular sections. This causes a disjoint between the mentalities of designers and developers that are extremely difficult to manage [9, 26, 28].

Designers often perform the role of producing ad-hoc solutions, reviewing and giving feedback on products etc., the primary measure of success being "working software". This can cause strain on the relationship between developers and designers [28]. Studies have shown that there is a substantial misalignment of attitudes and work practices between developers and designers, and successful cooperation between these two roles ties in strongly with the organisational culture and standard decision-making process used by the organisation [26, 28]. Elsbach and Stigliani [32] found that organisations that successfully implement design thinking tools usually include collaboration across teams from different departments, including marketing.

Often in agile spaces, UCD is only considered at the later stages of development or during the testing of the software [2, 26]. It was found that in agile software development methods, sprints became too short if user testing and usability testing increased [33].

Several researchers suggest a dual-track agile software development method. Using this method, UX designers work one sprint ahead of developers to ensure the designs are within the scope and that validated designs are delivered to the development team so that a tangible form of the proposed solution can be developed [3, 9, 33, 34]. The problem with this approach is that a single sprint usually does not allow the designer to understand the features they are addressing in the context of the business [20, 28]. Ideally, the UX team should conduct small-scale user acceptance tests throughout the development process to ensure that any change made to the designs during the development process still fits the user's expectations [34].

It is thus essential for development teams to have regular alignment meetings to ensure that the designs align with development capacity while still ensuring that the user's needs will be met [9, 28]. It is also critical in the UX process for a diverse group to evaluate the consequences of the suggested solution from their perspective and skillset to ensure that the team is aligned to achieve the end goal [9, 28].

2.5 Challenges between agile methodologies and user experience

The adoption of agile methodology has repercussions on usability as it prefers a minimalistic, "address it as it happens" approach over an in-depth analysis of the user requirements [4, 22].

The problem with the practices mentioned above is that it does not cater to cases where integration does not occur constantly or occurs unpredictably. It also does not consider that agile teams rarely follow the methodologies accurately in the practice [4, 22]. Usability designers that are fully integrated with the development team may lose track of the UX goals and the mere presence of a UX designer in meetings and planning sessions may not be enough to ensure adequate thought is given to the user experience [4].

Studies found that in Agile organisation UX design does not receive the necessary support and UX designers often not part of the development team, but are responsible for delivering designs for multiple development teams, reducing their effectiveness and efficiency [18, 26]. The most commonly used usability methods in agile software development environments include: heuristic evaluations, fast prototyping, individual inquiry and formal tests [18].

At the pace that agile teams need to release new features to the existing software, there is often not enough time to do adequate user testing [8, 18, 34]. There are often not enough pieces of the puzzle to effectively test a feature during a sprint, and user tests are often moved back to the end of the project. At this point, it is far too late for the UX researcher's findings to have any measurable impact on the feature being released and is often only added to later sprints and, in some cases, never addressed [34].

Agile teams are often averse to documentation since it is such a people-focused development methodology that prefers just-in-time requirement solicitations over in-depth investigations [4, 22, 35]. In the development team's fast-paced, product delivery mindset, documentation is often left on the back burner, then only appreciated when system maintenance needs to be done [14, 21, 35].

3 Methodology

The research philosophy implemented for this study was interpretivism, as it aims to explain the views and experiences of a group of people within a specific social setting. A qualitative research method was used to for data collection as it allows for the analysis of social phenomena and the collection of non-numeric data. An interpretive case study was conducted to gain an in-depth understanding of the agile organisation that was analysed. Twenty-one participants were chosen for this case study based on their relevance to the study through the selective sampling method, and data was collected by conducting semi-structured interviews with the selected participants. A thematic analysis is used to identify common themes and patterns within the qualitative data that was collected. Data was collected from Organisation X.

Organisation X is a small to medium software development company that offers analysis and design of a system and the development and maintenance of systems. The organisation employs a variety of roles from software developers, information designers, user experience designers, business analysts and project managers. The organisation works with various clients on various projects, each with a unique user base and system requirements.

4 Research Findings

The data collected was thematically analysed to assist to answer the research questions. Five types of challenges were identified, communication challenges, project constraints challenges, developer challenges, process challenges and design challenges. The agile principles that impede the implementation of empathic design were identified, and a list of critical success factors that were suggested by the interviewees were summarised. The themes and their subthemes are visually represented in Figure 1.

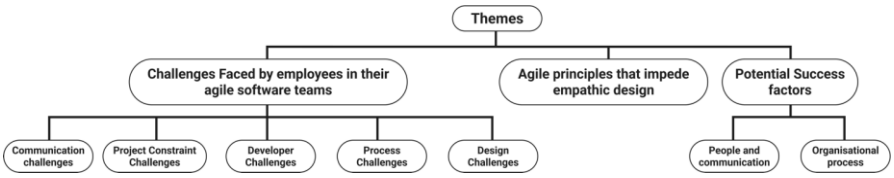

Fig. 1. Codes and related themes from interviews

4.1 Challenges faced by the Interviewees in their Agile Teams

The challenges faced by the interviewees were divided into five subgroups, namely: Communication challenges, Project constraints, Challenges faced by developers, Process challenges, and Design challenges.

Communication Challenges. In the communications challenge category, one of the biggest challenges faced by the interviewees in terms of implementing empathic design was client buy in. Clients tended to value the output of development higher than the process of designing empathic software. One of the developers that were interviewed, when referring to why their client does not buy into the design process on their project, stated that ..."business does not necessarily see the value in a certain feature being developed in a one way or a different way". One of the design team leads stated that they try to persuade their client that ... "It's actually wasting your money to try and build a system where you don't keep the user in mind." This aligns with findings by Bongiovanni and Louis [36] that found that the language used by designers and consultants differ and affect the buy in from clients. This is also in contradiction to agile principle: “Build projects around motivated individuals. Give them the environment and support they need and trust them to get the job done” as creates a barrier for designers to perform their work effectively.

Another challenge with implementing empathic design is the cost associated with user testing and the availability of user representative to test the software’s usability. Clients are often unwilling to pay for recruitment of users for either virtual or in person user tests. As stated by one of the design team leads … “they struggled to allocate a budget, or a good enough budget to adequately do user testing”. It is both costly and time consuming and clients often do not understand the value of implementing a proper UX process or do not have the resources to fund them. A design team lead mentioned … "Many clients think that they understand what UX means, but then aren't willing to pay for what UX actually is." Lermen, et al. [37] found that although preincubated startups implement a variety of qualitative UX methods, there is often a lack of quantitative feedback from users. They found that the higher the maturity of the organisation the higher the need for more agile UX practises are required to collect feedback form a user base [37].

Interviewees found the facilitation of communication between different stakeholders due to client availability challenging. The agile manifesto promotes customer collaboration over contract negotiations since it ensures the development team is aligned with the customer’s needs, but this is difficult to facilitate when clients are not available to provide feedback. Clients often are unsure of what they need and do not have a clear idea of the requirements of their product [38]. Clients may provide inadequate requirements to the business analysts or designers which can remain a problem all the way through to the development stage if regular alignment meetings are not held with the relevant stakeholders. Regular alignment meetings would mediate the challenges of communicating project constraints and help to manage the clients’ expectations.

One agile core principle state that “Working software over comprehensive documentation” while some participants stated that the management of knowledge through effective API documentation and light requirements documentation mitigates the challenge of being dependant on individuals for project progress. Requirements tend to get miscommunicated if there are several points people between the customer and the developer, and with that Agile promotes light documentation, many teams tend to forgo the proper documentation of requirements for verbal communication. According to Alvarez, et al. [38] it is essential that requirements are properly documented in order to anticipate and control any changes in the requirements that may arise during the course of the project.

During large projects it is often difficult to get representative form each stakeholder group as a dedicated member of the project team and often with government related projects interactions with the client are few and far between. This issue can be intensified by the proximity of the client to the software team as it is not always feasible to visit the client on sight to observe the end user or to demo to the client. According to Zamani and Pouloudi [39], distance inhibits shared understanding between members of a team and between a client and the software provider. Proximity enables more frequent interactions and allows for more effective communication [39].

Project constraints. The biggest challenge related to project constraints challenges with project budget. Often provision is not made in the budget to include design processes, or a project has a fixed cost and thus has limited allocated time and resources to create user centred products. In cases where organisations have insufficient budget for extensive and in depth design processes, literature suggest the use of agile UX [37]. Agile UX implement a combination of design thinking, lean startup and lean UX to encourage innovation and delivering value to users [37]. Another challenge that was discussed related to the availability of testers. In SME’s there are often a limited number of testers employed in the organisation and their time needs to be distributed between all the active projects. Because of the fast pace of agile it is often difficult for these testers to adequately test the product before the next phase of the project is initiated. Saeeda, et al. [40] found that the four main challenges faced with testing in large scale agile projects were a lack of system testing, a lack of acceptance testing, a lack of regression testing and a lack of integration testing. Because clients value time to market the team often is not given the opportunity to pilot test the product before it is released into production. Since the business analysis and design phase of the SDLC is often short this may cause edge cases that were not catered for during development to become prevalent only once the product is being implemented. Clients often do not do user acceptance testing due to a restriction on resources [40].

Challenges faced by developers. Developers indicated that time and budget constraints were to major factors that impact their work. This correlates with a model known as the agile triangle. The three dimensions of the agile triangle consists of value, quality and constrains [41]. This fell into the category of project constraints. According to Kothuru Chinnadurai [41] value should remain a fixed goal while the

constraints are changed throughout the project life cycle to maximise the value output. The budget constraints the developers experienced often affected the amount of time they were allowed to spend on certain features. This correlates with findings by Saeeda, et al. [40] finding that due to strict deadlines and a lack of resources developers often skip important processes to stick to project timelines. This could be due to the project being a fixed cost project or the client not buying in to the implementation of user centred design processes. This interlinks with the time constraints experienced by developers, as often spending time to improve a feature for the sake of the user experience was not feasible due to timelines and budget constraints.

Process Challenges. The biggest process challenge faced by interviewees related to the fast pace of agile. Designers found it difficult to effectively empathise with the user, define the needs and requirements, ideate on a variation of potential solutions, create designs and working prototypes as well as validating their assumptions through user testing while following the agile method. Designers also found it difficult to communicate the bigger picture of the project to developers if the project had not yet been effectively scoped out and analysed. Persson, et al. [4] explained on how UX design and software development processes can be adjusted to maintain quality and agility, a UX designer indicated that it is extremely difficult to create wireframes once the development phase has begun, as analytics and due diligence disappears, and the design team loses track and overview of the work that they are doing. Thus, the fast pace at which agile requires sprints to be completed is not an effective project management method for the design phase of a project.

Design Challenges. There are often requirement changes at a late stage of the SDLC, making is difficult for the project to remain user centred while meeting timelines. Developers may also sometimes implement changes to the designs without consulting the designers once requirement change are requested. This does adhere to the agile manifesto value stating “Respond to changes rather than following a plan” however this makes it difficult to ensure the minimum level of user experience is maintained throughout. Persson, et al. [4] suggests that designers need to take on an active role of reviewing the implementation of their designs during the development phase.

Agile Principles that impede empathic design. The biggest principle of agile that impedes empathic design, as mentioned by 12 of the interviewees, is the speed at which software needs to be developed as it does not allow time to complete rigorous research. Speed is also an inhibitor of creative design thinking, as a design lead indicated "I found designers often a bit slower than dev in terms of when the actual agile side of things". According to a study done by Acar, et al. [42] constraints can benefit creativity as proven by numerous startups where input constraints (time, money etc), output constraints (customer feedback) and process constraints (daily stand-up’s) can increase creative performance but that the creative process faces challenges after a constraint threshold has been reached. The goal is thus to identify the optimal level of constraints that will not inhibit the creative process and allow for innovation [42].

The interviewees commented that the design processes followed by Organisation X followed more of a Waterfall approach during the design phase. Meaning the entire project is scoped out and designed before moving on to the development phase. According to Stepanova [9] this is known as the "design-agency" model and describes this model as ineffective due to the heavy documentation handover. This can be mitigated by implementing a hybrid agile approach that allows the design team to conduct the design phase of the SDLC following the waterfall method, then switching over to agile once the development phase is reached.

The interviewees argue that to properly address the problem, the entire solution must be scoped out to cater for all situations and user stories. This allows them to have a holistic view of the problem [9]. Understanding the entire system allows the designers and business analysts to better fulfil their role as developer support during the development phase. The design team has overcome the "heavy documentation handover" by breaking the designs up into "Dev packages" that consists of enough work to fill a sprint, complete with handover notes and requirement explanations. This corresponds with the regular alignment meetings recommended by literature that allows for better quality UI development [9, 33, 34]. It is also recommended that designers should regularly have stand-ups, retrospectives, and sprint planning sessions with the development team as well as ad-hoc meetings to discuss any shortcomings that was noticed in the designs [9, 33, 34].

Recommendations. After an analysis of the themes that were prominently mentioned in the interviews the following recommendations can be made:

- If an Agile software team is experiencing a lack of client buy in with regards to UX design, it is recommended that the team take on a Lean UX approach. This way the team can maintain a minimal level of usability in the product that they are creating.
- Make use of heuristic reviews and rely on the design team's expert knowledge of the design principles if there are strict budget constraints such as a fixed cost project or if it is difficult to find users to perform user tests.
- If it is difficult to find expected end user to perform user tests with, use readily available people in the team's vicinity. This includes friends and family, as well as colleges. It is better to test with some users than to not test at all. The data gathered from such tests must be analysed with the knowledge that the tester sample does not perfectly match the target user group.
- Maintain light documentation to minimise the dependency on a small group of individuals who possess a large portion of the knowledge on a project. Team members may get sick or leave the company, or the team might expand, in which case new team members need to be onboarded and it is thus important to have a single source of truth from which to reference.
- Create sustainable API documentations and useful code comments. This allows new members to be onboarded with ease.
- Designers should create hand over documents for developers that are easy to consume. These "Dev Packages" should contain in depth information on the features

that were selected to be worked on in the upcoming sprint. The documentation should be maintained if any changes are made during the sprint.

Critical Success Factors. The biggest success factor that was identified during the interview process is the flexibility of Organisation X in the application of its agile principles to fit with the needs of their clients. This Hybrid Agile project management approach allows them to incorporate the strengths of both agile and waterfall into their projects. According to Adelakun, et al. [43] some of the advantages of Hybrid Agile include adaptability, developer happiness, increased product quality and early defect detection. Adelakun, et al. [43] also emphasises the usage of Hybrid Agile based on client preference.

Similar to the findings in our interviews, Adelakun, et al. [43] advocates strongly for adequate documentation to be done. While literature encourages minimal documentation [44-46], the design team at Organisation X found that light documentation is needed to avoid dependency on single individuals that are the sole owner of knowledge. The design team make developer handover files with in-depth explanations next to the high-fidelity designs to minimise the locations in which developers need to go searching for information. The development team documents all endpoints that have been created so that sustainable development can take place.

It is critical for the implementation of empathic design that all members of the software development team imitate the user at some level. This enables the team members to take on more of an observational role before they switch to the problem-solving role. This allows for the creation of more pleasurable and impactful products [10].

Organisation X implements Lean UX in low budget fixed cost projects, maintains a minimal level of usability through the practise of heuristic evaluations and following design principles. This is also Implemented when a project lacks the buy in from a customer to implement the full UX design process. According to Alhammad and Moreno [47] Lean UX has a lightweight nature that follows iterative processes based on design thinking, which allows it to fit well with Agile projects. Some of the challenges faced by Alhammad and Moreno [47] included that their research subjects found it difficult to fit Lean UX processes to fit into the short sprints required by the agile methodology, which aligns with the findings form the interviews conducted for this study.

5 Conclusion

The flexibility that organisations allow for in their agile processes can be a great benefit with regards to effectively matching the needs of their clients. The implementation of Hybrid Agile can increase the quality of the final product, increase the adaptability of the team, and increase the overall happiness of the team. The flexibility allows for more time to manage the knowledge regarding the project as well as increasing the allocated time for analysis and design. Teams can increase their empathy for their end users by imitating the user at each state of the product development cycle,

sharing the responsibility of user centred thinking. It is essential to maintain a minimum allowable amount of usability of the product by performing Lean UX practises, even if the project has a small design budget. Testing the product is critical to ensure the product is fit for purpose, usable and delightful.

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Overcoming Obstacles to Adopting Artificial Intelligence in Identity and Access Management

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Abstract. Cyber-attacks are on the increase, and are becoming more complicated as technology advances and affecting people as well companies globally. Advanced approaches to mitigating cyber-risk are required. One of the advanced approaches to managing cyber-attacks is the use of Artificial Intelligence (AI) in Identity and Access Management (IAM). The adoption of AI in IAM is slow as there are various obstacles encountered. This study establishes obstacles a survey using semi-structured questions. 15 participants working in the financial services industry as AI, IAM and cybersecurity experts were interviewed in the survey. Enablers for the adoption of AI in IAM were established from these participants as well. Several of the enablers gathered from the interviews are confirmed by literature. A number of interviewees highlighted high levels of maturity of IAM as a precondition for successful use of AI to support IAM. Furthermore, the interviews confirm organisations' uncertainty of AI capabilities, fears of job security and lack of AI skills.

Keywords: Identity & Access Management, Artificial Intelligence, Cybersecurity and adopting Artificial Intelligence

1 Introduction

Cyberattacks, especially automated attacks are on the increase due to a fast growth in bot traffic (Williams, 2022). In addition, cyberattacks are increasing and becoming more complicated (Mohammed, 2020). Some organisations are adopting Artificial Intelligence (AI) to improve identity and Access Management (IAM). IAM is a subset of cybersecurity and it focuses on aspects such as identification, authentication (e.g., role-based access control, rule-based access control, mandatory access controls and discretionary access controls), authorization, as well as the identity and access provisioning lifecycle (e.g., provisioning, reviewing and revoking access) (Gordon, 2015: 635–729). The global market of AI in cybersecurity is anticipated to grow by 23.6% from 2020 to 2027, reaching $46.3 billion **(**Meticulous Research, 2022).

Despite the potential value of AI, researchers such as Mariemuthu (2019) and Biallas and O'Neil (2020) observed in their studies that the adoption of AI is slow global-

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ly. This paper aims to identity obstacles to adopting AI in IAM and recommend enablers for its adoption in this subsection of cybersecurity.

2 Literature Review

2.1 The Adoption of AI In IAM

AI can be used in IAM to detect anomalies, for authentication, provisioning, responding to Distributed Denial of Service supporting decisions, handling incomplete and imperfect data and data reduction. Below are some examples of how AI can be used in IAM.

Anomaly detection – Traditional methods are no longer capable cope with modern attacks (Zhang *et al.,* 2022). Kanimozhi and Jacob (2019) proposed using Artificial Neural Networks to detect botnet attacks. Aljamal *et al.* (2019) suggests a combination of IDS, K-means clustering algorithms and the Support Vector Machine (SVM) classification algorithm to monitor behaviour on IT systems and the network. Furthermore, AI can identify regression and outliers (Campbell & Ying, 2011).

Analysing biometric information – Artificial Neural Networks (ANNs) can be used to compare fingerprints while confirming the distance between feature points (Sudiro and Lukman, 2015). Genetic feature learning networks and facial expression recognition to authenticate users (Verma *et al.,* 2019). Deep Convolution Neural Networks can be used to recognise the iris for authentication (Gangwar and Joshi, 2016). Recurrent Neural Networks (RNNs) can be used for voice recognition (Amberkar *et al.*, 2018).

Authentication – Benefits of intelligent authentication include efficiency, reliability, continuous protection and situation awareness (Fang *et al.*, 2019). A random forest algorithm can be used for multi-factor authentication combined with Neural Networks (NN) for monitoring typing speed and style (Zhang *et al.,* 2022).

Detecting Distributed Denial of Service (DDoS) - Deep learning (Li, 2018), K-Means and SVM (Jyothi *et al.,* 2016), Deep Learning, CNN and RNNs (Yuan *et al.*, 2017), K-NN, NN and SVM (Khalaf *et al.*, 2019) can be used to detect DDoS attacks.

Supporting decisions – AI can be adopted to support decisions where IAM is automated (De Ville, 2013).

Handling incomplete data, imperfect data and data reduction – K-Nearest Neighbour can be used to reduce data for analysis, handle imperfect data and input missing values (Triguero *et al.*, 2019).

Provisioning – Expert systems can be used for user provisioning (Qi *et al.,* 2007).

2.2 Obstacles Towards the Adoption of AI in Organisations

Due to limited literature on obstacles to the adoption of AI in IAM, the researchers considered literature describing obstacles to the adoption of AI in general and barriers to the adoption of AI in cybersecurity more specifically. A list of barriers or obstacles

as identified in the literature is provided below. The barriers are categorized using the Technology-Organisation-Environment (TOE) framework of Tornatzky and Fleischer (1990). Table 1 shows obstacles identified through literature review.

Table 1. Table showing obstacles identified through literature review

Obstacle	Explanation	References
Technology		
Security concerns	Data security concerns	Brynjolfsson & McAfee (2018), Ransbotham *et al.* (2017)
Technology capabilities	Lack of resources required to implement AI	Alsheibani *et al.* (2019)
Data quality	Poor data quality, lack of intent to share data, absence of huge volumes of data, insufficient historical data, unlabeled data	Shrivastav (2021), Thowfeek *et al.*(2020), (Ansari *et. al.*, 2022)
Organisational barriers		
Governance	Absence of regulations, collaborations, government involvement, frameworks for sharing data between business units, undefined roles and responsibilities, ill-defined accountability for algorithms , lack of aligned ethics and governance	Shrivastav (2021), (Stone *et al*., 2022)
Lack of skills	Lack of skills to evaluate, build and implement AI solutions	Alsheibani *et al.* (2019), Ransbotham *et al.* (2017)
Lack of executive support	Unclear business case results in lack of support from top management	Shrivastav (2021), Ransbotham *et al.* (2017), Alsheibani *et al.* (2019), Radhakrishnan and Chattopadhyay (2020)
Lack of funding	Inadequate funding is provided for AI across the organization – value not always clear - ROI	Shrivastav (2021), Alsheibani *et al.* (2019)
Unclear business case	Unclear about which aspects of AI will be of value	Alsheibani *et al.* (2019)
Perceptions of AI	Employees fear of change, fear of job security, unreasonable expectations of AI, inconsistent performance metrics	Shrivastav (2021), Alsheibani *et al.* (2019)
Operationalizing AI	Legacy systems not compatible with AI systems	Shrivastav (2021),
Environmental barriers		
Consumer trust	Privacy concerns	(Stone *et al*., 2022)
Geo-political factors	Absence of regulations, government involvement,	Alsheibani *et al.* (2019)

It is assumed that the obstacles to the use of AI in the Identity and Access Management will be similar to those described in Table 1. The next section describes the method followed to get practitioners' opinion on the obstacles of AI adoption in IAM specifically. In addition, these practitioners' suggestions on how to overcome these obstacles, were also elicited.

3 Method

A survey was conducted using semi-structured questions to identify obstacles to adopting AI in IAM. Fifteen (15) participants (professionals in IAM and cybersecuri-

ty) from four banks in the financial services industry in South Africa participated in the study. These participants were selected using purposive sampling. The designations of the participants were Head: Technology and Digital, Head: IT Security, Head: Logical Access, Head: Technology Risk, Senior Cybersecurity Engineer, CEO of a technology consulting company, a partner responsible for cybersecurity consulting at an audit firm, Enterprise Security Architect, Chief Information Security Officer, Assistant IT Audit Manager, Logical Access Expert and Head: IT Audit. The number of years of experience ranged from 5 to 11 years. The participants worked in both big banks and smaller banks or had done consulting work in banks. The interviews were conducted and recorded via Zoom and transcribed and analysed using thematic analysis guided by the TOE framework. The first part of the interview was on understanding their perceptions of the obstacles towards adoption of AI in IAM in the financial sector. The second part of the interview posed questions categorized according to the TOE framework on elements necessary for the promotion of the adoption of AI in IAM.

4 Findings

4.1 Obstacles to Adopting Artificial Intelligence in Identity and Access Management

In the survey conducted, the researcher asked the question, "What do you think are the obstacles to adopting AI in IAM?". Table 2 depicts the obstacles to adopting AI in IAM identified by participants during in the survey.

Table 2. Obstacles to adopting AI in IAM identified in the survey carried out

	Themes	Freq.
1	AI is a new concept	10
2	Legacy systems may not be compatible with AI technologies	4
3	The basics of IAM are not in place	4
4	Lack of AI skills	4
5	AI is considered an expense and management is not reducing costs.	3
6	Either or both a lack of data and poor data quality	3
7	Concerns over data security	2
8	Fear of AI taking over	2
9	Fear of job losses	2
10	Concerns over regulatory compliance	1
11	Lack of trust in AI	1
12	People not willing to change and embrace new technology.	1
13	Systems are not integrated	1

Listed below are themes that appeared the most frequent as obstacles to adopting AI in IAM. (1) AI is a new concept, for example participants stated that "…AI is still maturing…". (2) Legacy systems may not be compatible with AI technologies, for

example participants stated that "…Systems are not integrated…, …Banks still use legacy systems…" impact adoption of AI. (3) The basics of IAM are not in place, for example participants stated that "…some organisations are still struggling with IAM basics…". (4) Lack of data and/or poor data quality, for example participants stated that "…Lack of data…" impacts adoption of AI. (5) A lack of AI skills. (6) AI is considered a cost, for example participants stated that "…there are costs associated with adoption of AI…".

4.2 Measures to Address Obstacles to Adopting Artificial Intelligence in Identity and Access Management

The Technology Organisation and Environment (TOE) framework was used to obtain feedback from the participants and categorise the findings.

Technology Factors - The researcher asked the question: "From a technology perspective, what needs to be in place to promote the adoption of AI in IAM?". Table 3 contains the technological enablers identified in the survey.

Table 3. Technology enablers for adopting AI in IAM

	Themes	**Freq.**
1	Systems should be integrated	6
3	Quality data should be available	6
5	There should be infrastructure to store and process data	5
2	Experts such as AI, IAM and integration experts are required	4
4	AI use cases should be well articulated	3
6	Organisations setting up learning environments on platforms	2
7	Networks should be reliable	2
8	Data should be secured	2
10	IAM processes need to be reviewed and refined	2
12	Modernise legacy systems	2
9	Confirm service providers with AI technologies to be implemented	1
11	Technology needs to be robust	1
13	Ease of implementation and configuration	1

The most frequent technology related themes to adopting AI in IAM are listed below. (1) Technology should be integrated ("… APIs should be used to integrate legacy systems with AI technologies …"). (2) There should be AI, IAM and Integration skills,, for example participants stated"… The right skills should be in place …". (3) Data should be of good quality, for example participants stated"… Data should be of good quality as AI is based on learning …". (4) There should be infrastructure to store and process data. (5) AI business case should be well articulated.

Organisational Factors - The researcher asked the question, "From an organisational perspective, what key elements need to be in place to promote the adoption of AI in IAM?". Table 4 contains the organisational enablers identified in the survey.

Table 4. Organisational enablers for adopting AI in IAM

	Themes	Frequency
1	Top management support	8
2	A budget for AI adoption should be in place	6
3	Culture of innovation, learning and change	6
4	There should be AI training and awareness	6
5	AI and IAM skills should be in place	5
6	A well-articulated business case	3
7	Change needs to be managed	3
8	Governance of AI	3
9	A drive to implement AI	2
10	Leadership and strategy that drive AI adoption	2
11	A cybersecurity framework/programme needs to be in place	1
12	Cybersecurity needs to be a board agenda	1
13	Orgs. need to recruit the right people to support the AI initiative	1
14	Integration of technologies	1
15	Addressing risks associated with the use of AI	1
16	Acquiring platforms for using and exploring AI,	1
17	Creating efficiencies in IAM	1
18	Stakeholder engagement	1

The most frequent technology related themes to adopting AI in IAM are listed below. (1) There should be a budget for AI adoption. (2) A culture of innovation, learning and change , for example participants stated"… A culture that embraces change and accepts AI…". (3) AI training and awareness, for example participants stated "…Education and awareness on AI …". (4) IAM and AI skills, for example participants stated"… The right skills are required….".

Environmental Factors - The researcher asked the question, "From an external environment perspective, what elements need to be in place to promote the adoption of AI in IAM?". Table. 5 contains the environmental enablers identified in the survey.

Table 5. Environmental enablers for adopting AI in IAM

	Themes	Frequency
7	Regulatory bodies should provide guidance and expectations	10
2	AI training and awareness	4
9	Guidelines and best practices should be provided by industry bodies	3

1	AI and IAM skills are required	2
8	Financial regulators need to define standards to protect data.	2
3	Studying external AI success stories	2
4	Regulatory acceptance of the use of AI	2
5	Arms of the government need to be up-to-date with AI (e.g. police)	1
6	Engaging partners and vendors play key roles	1
10	Collaboration at industry level	1
11	External bodies should drive the AI initiative as a roadmap	1

The more frequent themes associated with Environmental enablers are listed below. (1) regulatory bodies should provide guidance and expectations, for example participants highlighted that "… Regulatory bodies should put in place laws on the use of AI ….". (2) AI training and awareness, for example participants stated"… Knowledge and capabilities of what AI can do in IAM…..". (3) Industry bodies should provide guidelines, for example participants highlighted that "… Industry bodies can help educate people and organisations in terms of AI, what AI can do and controls that should be in place ….".

5 Discussion – Obstacles to AI Adoption in IAM

The following obstacles identified through literature review were confirmed through the survey - lack of skills, legacy systems, systems not integrated, lack of trust in AI, fear of job loss, fear of AI taking over, poor data quality, security concerns, perception of AI and concerns over regulatory compliance (see Fig. 1).

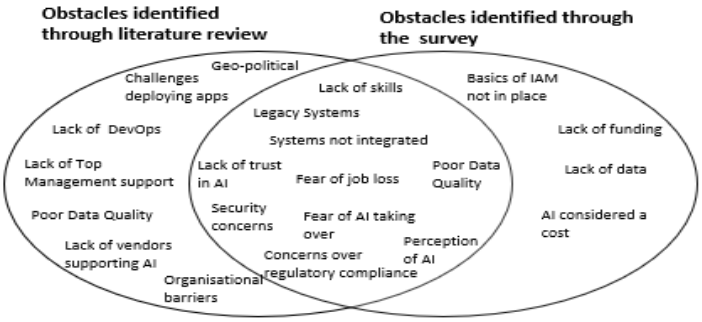

Fig. 1. – Verifying obstacles identified in literature review with obstacles identified through the survey carried out.

Basics of IAM not in place, lack of funding, lack of data and AI considered a cost were identified in the survey but not through literature review. More than one participant mentioned that IAM needs to be at an adequate maturity level before the use of AI can be considered. Note that the literature focused on the adoption of AI in organisations in general. Interesting enough important obstacles identified in the literature

were not mentioned by the participants such as (1) lack of top management support, (2) poor data quality and (3) lack of vendors supporting adoption of AI.

6 Discussion - Overcoming Obstacles to Adopting Artificial Intelligence in Identity and Access Management

From the themes identified in the data analysis and existing literature the following enablers for the adoption of AI in IAM are presented. The enablers are discussed according to the three dimensions of the TOE framework.

6.1 Technological Enablers

Modernising Legacy systems - AI technologies should be compatible with infrastructure, and data sources (Chen *et. al.*, 2023). It was observed in the survey that legacy systems may need to be replaced, upgraded/modernised or have interfaces built.
Integration of Systems -The survey carried out, established that IT systems should be integrated, Experts such as Integration Experts and System Architects should work together and networks should enable system integration.
Data availability and quality - To address lack of data and/or poor data quality, a data strategy and data a management policy should in place (Tyler *et al.*, 2016). In the survey, it was established that data should be structured, be of good quality, infrastructure should be in place to process the data, infrastructure to store data and process data should be in place, the network should be reliable and technology should be robust. Furthermore, there should be huge quantities of data.
Implementing IAM basics – From the survey conducted, it established that the basics of IAM need to be in place, IAM processes should be mature, the organistion should have IAM experts (this could be inhouse or outsourced) and an IAM solution should be in place.
Addressing security concerns – The survey highlighted that data should be secured and data protection standards should be defined.

6.2 Organisational Enablers

Top management support when adopting AI in IAM - Appointing a Chief Data Officer and highlighting the importance of AI is crucial (Solaimani *et al.,* 2023). Top management should understand the basics of AI (Butner and Ho, 2019). There should be commitment to adopt technology AI from executives (Alsheibani *et al*., 2019). Executive management should be engaged to obtain their buy-in (Alsheibani *et al.*, 2020a; Alsheibani *et al.*, 2020b). An AI strategy should be drafted, approved and implemented and it should be aligned to the business strategy (Pumplun *et al.*, 2019). A business case for the adoption of AI in IAM should be documented and presented to the appropriate forums (Solaimani *et al.,* 2023). The business case should articulate the benefits of AI in IAM such as, AI should improve process efficiency (Alsheibani *et al.*, 2020a, 2020b).

Adequate funding for the adoption of AI in IAM - A budget for adoption of AI is crucial for the adoption of AI (Chen *et. al.*, 2023). in IAM. Top management support, AI strategy and business case for adoption of AI in IAM are important for the budget to be approved by top management. Executive management should understand the basics of AI and there should be commitment to adopt new technologies (Solaimani *et. al.,* 2023). AI strategy and business case were discussed above.

Skills available to adopt AI in IAM - Lack of AI and IAM skills can be addressed through learning platforms, partnership with vendors, multi-disciplinary collaboration and talent management. When AI and IAM skills gaps exist in the organisations vendors can be used to address the challenge. However, the vendors should be accessible and provide reliable services (Chen *et. al.*, 2023). The organisation should have programs to reinforce learning, attract talent, partner with recruitment companies, and leverage on internal staff (Lee and Shin, 2020). There should be learning and development plans to familiarize everyone with AI (Agrawal et al., 2017). In addition to the above, It was established in the survey conducted that the organisation should acquire learning platforms to promote learning and adoption of AI. Inter-departmental communication and corporation is important to fill the skills gap when adopting AI (Chen *et al.*, 2023) in IAM. Organisational structures should ensure there is multi-disciplinary collaboration (Bughin *et al.*, 2017a). It may be difficult to recruit professionals with bit AI and IAM skills, in such instances AI experts should work closely with IAM experts.

Addressing fear of job loss and fear of AI taking over - Fear of job loss and AI taking over can be addressed through training (discussed above) and an innovation, learning, change & agile culture. The organisation should have a change management strategy which encourages employees to adopt to new conditions (De Cremer, 2019). The organisation should establish an agile culture which promotes the adoption of new technologies, continuous learning and adjusting to market trends (Brynjolfsson and Mcafee, 2017; Ransbotham *et al*., 2017).

Management of perceptions of AI - The perception of AI is influenced by factors such as AI success stories, Government involvement and AI governance. Based on feedback from the survey carried out, studying organisations that AI has been successfully implemented has a positive impact on the perception of AI. Government support is crucial to assist organisations innovate (Chen *et. al.*, 2023). Executive management should establish authority and governance over AI (Alsheibani *et al.*, 2020a) to build trust in AI.

6.3 Environmental Enablers

Trust in AI - Trust in AI is impacted by factors such as the existence of regulations governing the use of AI as well as AI Governance in organisations. Therefore, regulators and regulatory bodies should provide guidelines on the implementation of AI through laws, standards and frameworks (Lee and Shin, 2018).

A regulatory framework to guide adoption of AI -The survey carried out established that regulatory framework that provides guidance on the adoption of AI is required, regulators need to be aware of the developments in AI, regulatory bodies should em-

brace AI. Organisations should actively monitor changes/ new regulations (Solaimani *et al.,* 2023). Regulators should constantly monitor the change AI landscape and provide appropriate guidelines (Butner and Ho, 2019).
Vendors supporting AI - Should there be no vendors supporting AI, the organisation should consider training and talent management to build the necessary capacity and skills in terms of IAM and AI expertise.

7 Conclusion

This paper established obstacles to adopting AI in IAM and enablers for the adoption of AI in IAM. While obstacles to adopting AI in IAM exist, it is possible to overcome barriers through the enablers identified in this paper. It was noted that technology and organisational factors are within the control of the organisation. Environmental factors may not always be within the control of the organisation for example, regulations. In the event where there are no or minimum regulatory guidelines (depending on industry and size of the organisation), it may be advisable to engage the industry regulatory bodies to ensure there is alignment in terms of expectations from the regulator. From the literature and the survey, it is clear that government has an important role to play in the adoption of AI. In addition, higher education institutions should adopt curricula to reduce the gap between what industry needs and what is taught regarding cybersecurity and AI. Limitations include a small sample size: only four banks were considered in the sample. As such, the obstacles and enablers identified towards the use of AI in IAM suggested here, may not exhaustive. In addition, the enablers are more general and applicable to the adoption of AI in general due to the fact that most of the banks are still in the process of implementing AI for IAM.

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Investigating Automated Grading Techniques in Effectively Teaching Advanced Excel to Large Groups Of Accounting Students

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Abstract. The global student population is growing while faculty size remains constant. Lecturers shoulder an increasingly heavy teaching burden with concomitant pressure to increase their research outputs. Automated marking can alleviate the teaching load on lecturers, especially when the automated marking setup does not demand additional programming skills. This case study is an in-depth description of a course in advanced Excel for accounting students, and how it changed from paper-based assessment to fully online assessment. The move to automated assessment was motivated by large and increasing student numbers and limited lecturing resources, a phenomenon particularly salient in developing countries, where the case study is situated. An online assessment structure was developed by the lecturing team since the university does not have additional funds for costly automated grading tools. It used existing resources such as the university's learning management system and implemented simple string matching as opposed to more complex semantic similarity approaches. We found the success of the automatic grading depended on two aspects: the students adhering to a clearly defined process during assessments, and the Learning Management System's (LMS's) offerings in terms of grading functionality. The LMS used in the automating grading system described here, offered only basic matching functions for grading but no text manipulation functions required to build more robust and general-purpose grading solutions. This highlights a possible gap for LMS providers to address. In this case study we also touch on lessons learned in automated marking, improving marking efficiency, and managing the constraints of the available tools.

Keywords: Automated marking, Automated grading, Excel, Online Assessment, Pattern matching.

1 Introduction

Stress and multitasking often blindside lecturers. Obuh [1] lists several reasons for the lack of work-life balance, including high teaching loads, tight marking deadlines, and growing student numbers, without the equivalent of additional lectures appointed to ease the load. Fuelling the problem further is a growing focus on research outputs to fund public universities [2]. Reporting of burnout among lecturers has increased dur-

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ing and after the COVID-19 pandemic [3, 4]. Lecturers become stressed and overwhelmed due to the added pressure of "compulsory use of new technology" [5] and actively search for tools to help them regain control of their growing workload.

In this study, we discuss a specific method that we, as lecturers, used and are still using to manage the marking load of more than 700 second-year students taking a compulsory second-year module, focussing on advanced applications of Microsoft Excel (only described as Advanced Excel in the rest of this paper). The number of registered students is steadily growing due to the drive towards digital insight acquisition for students in the various faculties outside of economics. Impetus is added by simultaneous demands from industry that graduates possess spreadsheet skills. Despite the growing student numbers, the size of the lecturing team remains constant.

While this case study describes one assessment method, it may prove useful to educators who face similar problems, and support them in implementing small changes that may spare them considerable effort.

Our main research question is: How can automated marking best be used to efficiently and accurately assess large groups of students? We will also touch on lessons learned in automated marking, improving marking efficiency, and the constraints of the available tools.

2 Background

The road that led us to pose this question, can be traced back to the original assessment method of the module described in this paper. Traditionally, in face-to-face teaching, students completed paper-based tests.

This was also true for the Advanced Excel module. Students sat for their assessments in computer labs, each with an Excel file to complete, and the instructions on a piece of paper. They had to complete the exercises on the spreadsheet and copy the formulas onto the paper, which was then marked by a team of lecturers. The final marks were manually entered into the Learning Management System (LMS) by an administrative assistant. The exercise was labour-intensive and error-prone.

When the Covid-19 pandemic hit and all in-person interaction was curtailed, instruction and assessment were abruptly moved online. The Advanced Excel lecturing team had to implement the online assessments themselves and also had to complete all the marking by themselves. The students in their turn had to adjust to attending virtual lectures and a new process of completing their tests.

Setting tests online formed one aspect of assessment, but another equally important issue was the marking of the online tests. The Advanced Excel module demanded that the students' formulas be marked and not the just resulting value, as is done in many introductory Excel courses. However, the lecturing team had no other tools at hand than the University's LMS. We set about implementing online tests that could be partially automatically marked. This was done using the built-in pattern-matching functions of the LMS to assign scores to each answer, which was in the form of a short-answer question. This solution offered some relief but still required human intervention to assign marks to partially-correct formulas. This case study illustrates our jour-

ney towards automating Excel assessments, and the lessons we learned (and are still learning!) along the way.

3 Literature Review

A short literature review was performed to position our study. We identified a considerable corpus of academic literature on automatic grading (or marking as it is also called) but we start by mentioning that Excel is increasingly seen as a sought-after skill for various graduates. We also review the position of the lecturers who teach it.

3.1 The growing pressure on lecturers

The global Higher education (HE) sector is a rapidly changing area of work [6]. Class sizes are growing and the preparedness levels of students are diverging. Repercussions come in the form of increased marking load and the diversity of student needs. (Student needs range from a need for counselling, to learning and study skills development). The preparation and delivery of courses require a significant investment in time of the lecturer. All these considerations put extra pressure on lecturers [7] to meet these demands.

3.2 Excel as a sought-after graduate skill

Excel is an essential skill required by Accounting graduates to enhance their employability when entering the accountancy profession [8]. It is also a skill that is increasingly demanded by a variety of other disciplines [7- 10].

Formby, Medlin and Ellington conducted a study at their university to identify Excel skill sets that were deemed necessary by the future employers of their current students. They surveyed advisory boards, recruiters, and various other relevant parties and found that Microsoft Excel was ubiquitous in business. The need and opportunities for Excel based analytical skills are therefore widespread and pervasive. They recommended that
universities institute appropriate curriculum enhancements to improve their graduates' competitive marketability [11], [12].

3.3 Innovative marking (or grading) tools for Excel

Automated assessment tools are an active field of research. The terms marking and grading are used in literature to refer to the same concept. Many automated marking systems for programming assignments have been documented [13] and they show that the available technology architecture determines the benefits [14].

Assessment of writing falls into one of two forms: Automatic Essay Scoring and Short Answer Grading. The automated marking systems designed for grading essay questions are necessarily more complex than those grading short answers, as essays require text understanding and analysis [15].

Assessment for large classes requires additional functionality for the coordination of a lecturing team consisting of lecturers, tutors and teaching assistants. Enterprise level products include Moodle Workshops, Turnitin GradeMark, Waypoint, WebMark, and newer systems such as LightWork, RemarksXML,Blackboard Grade Centre, and Turnitin 2 GradeMark [16].

McNeill [17] provides a list of desired attributes for automatic grading systems after listing various automated grading systems for Excel assignments. Graders for generic Excel assignments have been written using Microsoft Access [18] and ASP.Net [19]. Other grading systems are provided as textbook supplements such as SAM (Cengage Learning) and SNAP (Paradigm Education Solutions). A version of SIMnet (McGraw-Hill) grades student formulas by comparing the formula as a text string to the solution text string, but only exact matches are counted as correct. Various publisher evaluation tools for spreadsheet grading simulate an Excel environment (such as SAM, SIMnet and Pearson's MyAccountingLab) and provide immediate grading and feedback to students. Very few of these systems accommodate instructor-developed spreadsheet assignments. McNeill identified a need for a grader that manages customised and more complex spreadsheet assignments. He developed MAGE as an Excel add-in [17].

Hekman [9] also investigated Excel automatic graders and found a variety of solutions written by individuals, ranging from files submitted through web pages [20] to spreadsheets with embedded macros [21]. One automatic grader required the students to complete a spreadsheet and complete an online quiz based on the spreadsheet [22]. He concluded that most of the autograders require dedicated programming for each assignment, and that some can grade graphs as well, but that none are completely automated without instructor interaction. Using the LabVIEW programming language, he developed a completely automated program to grade spreadsheets and graphs. The program uses ActiveX to read information about each worksheet in an Excel file, and communicates with Microsoft Outlook through ActiveX which allows the downloading and grading of students' homework submissions. For each submission, the program sends an email reply to the student with feedback on their submission.

Sheludko [23] examined automated assessment tools specifically for spreadsheet assignments. He tested various examples of spreadsheet models that contain self-assessment functions [10]. He found them to represent simple test cases where the spreadsheet processor uses data validation functions to compare single cells with reference values. Many of them do not test the formulas but only the final answer, and many need the teacher to manually review the tests, and collect the marks themselves. Adding new assignments requires lecturers to edit the code of the automated marking tool.

3.4 Free marking tools currently available

There are few free marking tools available, and even fewer spreadsheet marking tools in particular. A new automated Excel marking tool that is freely available (see [23]) makes use of the Google Cloud environment but it demands a considerable in-

vestment of time from the lecturer to set up. When all Excel files have been set up and sent to the marking tool, the final grades are received and this requires an additional step from the lecturer to upload the marks to their LMS.

3.5 The need for using technology to assist in marking assignments

The use of technology in the process of marking assignments and assessments has proven benefits for both students and faculty. Students benefit from even the most basic automated assessment in the form of immediate feedback and faculty benefit by being freed of many hours of marking.

Feedback is a critical component of teaching, be it summative or formative [19]. Automated feedback can be applied on a formative basis or to support summative marking, and technology can be effectively harnessed to do so as class sizes grow. It simultaneously shortens turnaround times which satisfies learner expectations [24]. Students may enter incorrect answers into their tests, convinced they are correct. An immediate response is pedagogically important [25]. Even rudimentary feedback provided by an automated assessment system can immediately provide students with information about the correctness of their solutions. To see the correct answer even in the absence of any feedback message, guides a student towards the required response. Such personalised feedback is even more important in large groups [14]. Accuracy of marking is crucial [26].

The workload of teachers may be drastically reduced by automated assessments, as manual assessments are very time-consuming [27]. The phenomenon of automated assessment is here to stay since the number of students is growing while the teaching staff numbers remain constant. In addition, automated assessments are more consistently graded which is an advantage when compared with grading done by humans [14].

4 Method

Case study research can be used to illuminate one's understanding of a complex phenomenon and can be used to gain an understanding of an issue in a real-life setting. It is both exploratory and explanatory, answering the how and why question, and sometimes also the what research questions. Outcomes can lead to an in-depth understanding of processes, practices and relationships [28].

In this paper, we use a single qualitative case study approach to show how we implemented automatic grading of advanced Excel formulas using only the existing functionality of a well-known learning management system. It is a pragmatist representation of our own experiences, where we focused on an existing system and are still effecting stepwise improvement on this system. We describe the problem and how we are addressing it, in the hope of contributing a practical solution that may be implemented by others.

The case study describes a single-semester course in Advanced Excel and how the grading of assessments changed over time, from paper-based to fully online. It is both

exploratory and explanatory in the sense that we investigated other approaches to inform ours, and then describe our attempted solution toward automated grading of assessments with the tools we have at our disposal.

5 Description

The Department of Informatics at the University of Pretoria presents an Advanced Excel course as a service module to second-year accounting students from the Economics and Management Sciences faculty. It is a semester module that caters to more than 700 students. It teaches advanced concepts in spreadsheets and query languages, empowering students to solve complex problems in the real world. The two departments collaborate on the content and adjust it regularly to ensure the most applicable functionality of Excel forms part of the curriculum. It remains the lecturer's responsibility to know all the content.

The Advanced Excel module is taught weekly in computer laboratories, accommodating roughly seventy students per session, with 12 scheduled sessions of 2 hours each. The content is thus repeated 12 times every week. In every practical session, there needs to be one lecturer and one teaching assistant. The team consists of two permanently appointed lecturers and two assistant lecturers (postgraduate students), and two to three teaching assistants. Seeing that the teaching assistants are still undergraduate students, they assist with administrative activities and do not present lectures.

An assignment is due per study unit, for the students to practice their newly acquired spreadsheet skills. These assignments have to be marked promptly and feedback provided to the students.

Assessments were traditionally performed on paper. Students attended the computer labs at pre-arranged times and were presented with a selectively empty Excel file, where they had to complete formulas on the spreadsheet according to questions on a paper test. Students then had to write the formulas on the answer paper.

When the COVID-19 pandemic hit, this face-to-face model was instantly replaced by an online lecturing and assessment process. The lecturers took turns recording walkthrough videos mirroring the material presented in class, and made it available to students weekly. One online class per week was presented to all 700+ students where the video content was reiterated and question-and-answer sessions were held on the study unit content. This practice shortened the class time and freed up some time for the lecturers to implement the assessments online. The team used the time to migrate the assignments online, and to create online assessments. The assignments and assessments were created as online tests on the LMS. The team had to cope with the workload as no change was made to the Advanced Excel team either during or post the COVID-19 pandemic.

The expense of purchasing automated Excel marking tools was and is prohibitive. The team started experimenting with specific BlackBoard LMS tools to determine how much of the assignment and assessment marking could be automated. The ap-

proach required careful planning and structuring of assessments, and instructions to students to complete the online tests.

The first question in each online test instructed the students to download an Excel file (which contained the instructions) and save it to their device using their student number. Students had to keep saving their Excel files as they worked, in case of a power cut or computer malfunction. The contents of the online test were saved automatically (because it was running on the LMS) but saving the Excel file was the students' responsibility. Each test question required the students to copy the formula from a certain cell and paste it into the space provided in the online test. The last question of each online test always instructs students to upload their Excel files to the LMS.

Many of the simpler functions were set to grade automatically using the Match functionality of the LMS. It performed string and pattern matching (see Figure 1).

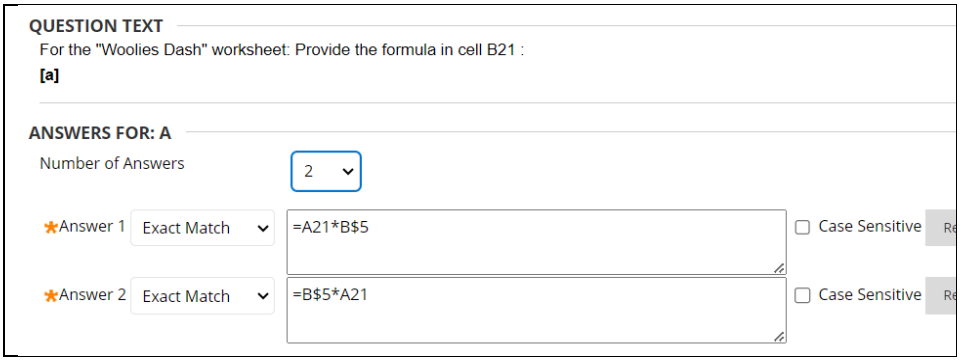

Fig. 1. Online test question setup specifying possible answers using the Match functionality.

Many formulas, although longer, were sufficiently simple so that most of the possible correct combinations could be specified (see Figure 2).

Copy the formula from cell K9 of the "Penalties" worksheet, and paste it in here.
Answers for: a
=IF(B9=J$3,K$3*G9,IF(B9=J$4,K$4*G9,K$5*G9))
=IF(B9=J$3,G9*K$3,IF(B9=J$4,K$4*G9,K$5*G9))
=IF(B9=J$3,K$3*G9,IF(B9=J$4,G9*K$4,K$5*G9))
=IF(B9=J$3,K$3*G9,IF(B9=J$4,G9*K$4,G9*K$5))
=IF(B9=J$3,G9*K$3,IF(B9=J$4,G9*K$4,G9*K$5))
=IF(B9=J$3;K$3*G9;IF(B9=J$4;K$4*G9;K$5*G9))
=IF(B9=J$3;G9*K$3;IF(B9=J$4;K$4*G9;K$5*G9))
=IF(B9=J$3;K$3*G9;IF(B9=J$4;G9*K$4;K$5*G9))
=IF(B9=J$3;K$3*G9;IF(B9=J$4;G9*K$4;G9*K$5))
=IF(B9=J$3;G9*K$3;IF(B9=J$4;G9*K$4;G9*K$5))

Fig. 2. All possible combinations of a simple IF statement

When students used innovative formulas that still performed correctly, these formulas were added to the list of correct answers, and the LMS immediately updated the marks.

While the automatic grading of the simpler formulas was automatic, the team needed to manually grade the complex formulas (see Figure 3). The complex formulas were difficult for the students to complete and students sometimes attempted only part of the formula. Then the team allocated marks accordingly.

Formula for automated recommendation

```
=IF(NOT(OR(K36:M36)),"Reject",IF(OR(AND(K36,NOT(OR(L36:M36))),AND(
OR(L36:M36),NOT(K36))),"Further Evaluate","Accept"))
```

Unit Price formula

```
=IF(ISBLANK(J24),"-",
VLOOKUP(
IF(VLOOKUP(J24, L3_Products, 3, FALSE) = 1, J24, L24),
CHOOSE(VLOOKUP(J24,L3_Products,3,FALSE),L3_Price1,L3_Price2),
2
VLOOKUP(J24,L3_Products,3, FALSE)>1)
)
```

Shipping formula

```
=INDEX(
(Shipping1,Shipping2,Shipping3),
VLOOKUP(O19,L3_States,3,FALSE),
MATCH(O20,L3_ShippingMethod,0),
MATCH(O21,{"Standard","Preferred","Most Preferred"},0))
*M32
```

Fig. 3. Examples of complex formulas in the module

Sometimes students use blanks in their formulas, because it aids in the readability of the longer formulas. This works correctly in Excel, because Excel ignores blank spaces inside formulas. However, the student then gets zero because the basic text match on the LMS automated marking does not work. We had to request students to remove any blanks from their formulas before copying them onto the online test. A simple pre-processing function from the LMS that allows the removal of blank spaces from the answer text, would have been invaluable.

The LMS also disallows the uploading of images and therefore the grading of any charts or graphs in Excel, had to be done manually. This limitation on the part of the LMS forced the team to download every student's Excel file, opening it, inspecting the charts and then entering the grade on the online test. This is time-consuming and forms one of the drawbacks of the process.

When all manual grading is done, the grades immediately reflect in the Grade Centre of the LMS. A significant advantage of the online grading system, is that the pre-

viously in-person perusal process is now more efficiently done online. Perusal is easily accomplished by opening the assessment for students during a pre-arranged time. The entire test is displayed, showing the students' responses, the correct options, and the grade earned for each answer. To query the grading of any question, students are provided with a link to a Google Form. The form contains a list of all questions in the assessment. A student can enter their query at any relevant question number. When perusal closes, the team checks all queries and re-grades accordingly. This happens directly on the LMS's Grade Centre and therefore the marks are immediately available.

6 Discussion

The research problem spotlighted in this paper focuses on how automated marking can best be used to efficiently and accurately assess large groups of students. An implementation of automatic marking of assessments for an advanced Excel module with over 700 students was used as a case study. We as lecturers of the module used existing tools available, in the form of the university's learning management system, to create online tests containing basic text-matching functions of short answers. No additional programming skills were necessary to implement the online tests. However, with such simple tools, it was impossible to fully implement autograding. The more complex formulas had to be marked manually.

While such an implementation is far from being fully automated, it still provides three main advantages: faster and accurate marking of shorter answers, transparency of marking and immediate feedback to students. The last aspect, immediate feedback, offered an unexpected bonus. Students used it as formative feedback. This became apparent to us when we created short online tests for students to complete during their practical sessions, to familiarise them with the process of completing an online test. The incentive to complete the quick test was that it would serve as an attendance mark. Therefore the test settings were such that the students could immediately see the correct answer upon submission. They could also retry and resubmit to get a better mark. It was an immediate learning opportunity for them to see that all aspects of their formula had to be correct before they received a mark. Seeing the actual formulas is better feedback than seeing a simple mark awarded [18], and eliminating the time lag between submission and feedback [9] offers an excellent learning opportunity. Matthews et al. [19] and Cutting et al. [24] emphasise the importance of immediate feedback as a key component of successful learning among students.

The quick tests could only be implemented for the short formulas. However, leaving the complex formulas for class is not necessarily a failing. Fenwick [30] found that entirely automated marking systems deny students formative feedback from more experienced programmers. Doing the exercises in class increases their opportunity to correct errors in their practice by consulting with the lecturer.

Assignments were implemented in the same way - as online tests that could be accessed throughout the week and resubmitted repeatedly, with the correct answers available after each submission. We saw that students also used their assignments as

learning opportunities. To receive better marks, they revisited their Excel files, replaced their erroneous formulas with the correct ones, and resubmitted the assignment. The enthusiasm of many students to retry and resubmit, mirrors the finding from Blayney and Freeman [29] who saw that self-assessment feedback improved the attitudes of students to learn important concepts.

The module was structured in such a way as to keep the student working consistently to keep up with course content and to keep practicing the assessment process. When students repeat the process during formative assessments, they get familiar with the examination process which allows them to better focus on content during summative assessments.

The limitations of the automatic marking described in this paper lie in the lack of preprocessing functions in the LMS for the automatic grading of complex formulas. The formula is entered as a short answer, and simply compared to a set of strings representing correct answers. Short answers are easier to mark than essay-type answers, although the answer has to be checked precisely before awarding marks. Nevertheless, the basic match functions of the LMS (used by the authors of this study), are not sophisticated enough to allow the implementation of pre-processing functions. The inability of the LMS to accept images as answers presented another significant limitation. It disallows image uploads, preventing students from copying their graphs onto the online test. This exponentially increased the marking time. Each student's Excel file had to be downloaded and opened before a mark could be awarded to any graphing or charting questions. Interestingly enough, the conditional formatting results could be copied to the online test because the content represented text and not images.

Another set of limitations lies in the students' use of the system. The complicated process the students have to follow in terms of downloading the file, saving it on the local machine's hard drive using their student number, copying each formula as they work to the online test, regularly saving their Excel file and finally uploading their Excel file to the LMS, is too onerous for many. In the stress of implementing the Excel operations for the test, they forget certain details of the process. There are various common errors students make when completing an online test. They use blanks in their formulas and forget to remove them for the online test. They forget to copy their formulas to the online test before the time runs out, or they forget to upload their completed Excel file at the end of the test. Invigilators have to keep reminding them and despite repeated communication of instructions, students still forget. This causes them to lose many marks unnecessarily.

Marking efficiency was improved by assigning certain questions to be marked by specific team members. The LMS assisted in allowing the team to work on a single question at a time. Marking is significantly faster when the team members each focus on one question in the assessment.

Further improvements that the team hopes to pursue include engaging with the LMS administrators to create a better pre-processor for the text matching functions, and attempts at simplifying the assessment process for the students.

7 Conclusion

The question pursued in this paper pertains to ways that automated marking via LMS can be harnessed to efficiently and accurately assess large groups of students in an Excel module. We found that an effective auto-grading system depends equally much on the process of test-taking than on the marking functionality. We found that the speed and efficiency of the marking depend on how accurately the students follow the test instructions. The case study ultimately echoes the literature in that automatic grading for advanced spreadsheet examinations does not allow a completely hands-free approach. This is because the complex formulas each carry a high mark value, and have to be partially graded. The simple formulas may be marked automatically, but the complex formulas still need to be checked and graded manually.

The tools used in this case study represent standard LMS functionality and require no programming skills to implement. However, the simplicity of the matching tools in the LMS proved such a constraint that the manual marking load far exceeded the questions that could be automatically marked. Despite this drawback, a significant improvement was realised in the perusal process as well as in terms of the marks accurately reflecting on the grade centre throughout.

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Navigating Digital Health Research Ethics: Insights from a South African Context

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Abstract. Research ethics committees are responsible for promoting academic integrity in research projects. They must ensure that researchers abide by the code of ethics that are relevant to the type of research being conducted. Digital Health research, which is at the intersection of information systems research and health research, is categorized as health research by South African research ethics committees. This results in researchers following often unnecessary research ethics processes prior to commencing their research project. This research uses the first author's PhD research as a case study to set the scene for Digital Health research ethics processes. A content analysis of three ethics policy documents revealed that there is no concrete definition for Digital Health research, which consequently leaves a gap in the research ethics processes. This led to recommendations aimed at research ethics committees and the relevant research ethics policy makers.

Keywords: Digital Health research, research ethics committees, information systems research, gaps in research ethics processes.

1 Introduction

The definition of Digital Health is expanding, with researchers now including medical terms such as genomics, software related components such as Artificial Intelligence (AI), clinical practice techniques such as telemedicine, and hardware devices that interact with people such as wearables [1]. This definition supplements those used in 2011 [2] which placed more emphasis on the virtual health record as well as associated hardware and technology devices. The extension of Digital Health's definition can be considered a contentious issue due to the research ethics implications of Digital Health research. Digital Health's adoption into healthcare settings globally [3] has consequently sparked an increase in Digital Health research projects in recent years [4]. Apart from the expansion of the definition of Digital Health, it could be argued that the term Digital Health is being mis-used or mis-understood. In some cases, Digital Health is sometimes used inter-changeably with health informatics which is a separate field that combines healthcare and information systems with a stronger focus on healthcare data [5] rather than placing a focus on technology design elements.

Research ethics committees are tasked with ensuring that research is conducted in a manner that protects research subjects whilst promoting the beneficence of the study

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within the relevant context [6]. Due to the inconsistent use of the term "Digital Health research", Digital Health can sometimes be gravely misunderstood, resulting in increased ethics approval turnaround times and frustration for the researchers who are conducting low risk projects which do not involve interaction or collecting data from patients. Committees tend to enforce unnecessary and excessively strict requirements on Digital Health researchers to the extent that it could be described as "the weaponization" of research ethics committees.

This research, based in South Africa, used a qualitative approach by considering the first author's current PhD research (henceforth referred to as "the PhD"). The PhD was used as a case study to set the scene of this research. A content analysis, which is a method used in healthcare research [7], was used to analyze three research ethics policy documents to determine whether there is an adequate definition for Digital Health research and whether it should be regarded as health research. The results of the content analysis, which used three cycles of coding, were combined with the insights from the health research application enforced by the research ethics committee on the PhD.

Recommendations were then formulated to simplify the ethics processes for Digital Health research projects. The recommendations, which include a decision chart were formulated for research ethics committees and policy makers. The recommendations were formulated with cognizance to the critical role that research ethics committees play in ensuring scientific integrity and participant safety.

2 Background

A Ghanian PhD candidate reflected on an experience with ethics review processes related to Digital Health [8]. That author explains the lengthy ethics application process which applies even to "non-clinical" research. The ethics application process was described as inconsistent and duplicated in some situations. This research uses a similar approach by using the PhD as a case study. Case studies present problems with real life contexts [9] which supports the interpretation of pragmatic research.

2.1 Case study

The case study with the working title "Digital Health: A Live Healthcare Console for Public Health in Gauteng, South Africa" focuses on the development of an information systems design model to make non-patient related information such as hospital bed occupancy available in real time to key stakeholders for the public healthcare system in South Africa. The research does not involve the development of a software artefact, nor does it investigate any sensitive data stored on existing healthcare systems.

The case study utilized three literature review phases, which led to an understanding that there is a lack of real time information available to key stakeholders. An evaluation of existing Digital Health design models was then conducted to determine whether an existing model could be used to solve the challenges experienced within

the Digital Health systems implemented in Gauteng (South Africa). Once it was determined that a contextually relevant model does not exist, it was decided to create a new model using lessons learnt from existing models.

To create a contextually relevant and actionable model, it was necessary to engage with key stakeholders within the public healthcare system. Semi-structured interviews were designed to engage with relevant stakeholders, which included healthcare workers and managers. No patients or otherwise vulnerable members of society were included in the study and no patient data were consulted. Supported by the worldwide adoption of online meetings, MS Teams was used to conduct all the interviews, preventing the need for the first author to physically visit any healthcare facility. The ethics and gatekeeper permission application steps are presented in the next section.

2.2 Ethics approval process

It would be reasonable to assume that the first author should apply for research ethics clearance from the University's college ethics committee at which he is registered. The first author's prior experience with Digital Health research however, led to the conclusion that "healthcare related research matters" are dealt with through another college within the University due to the nature of the research. **Table 1** is an explanation of the question categories that were asked on online research ethics application form.

Table 1. Digital research ethics application form question categories

Group	Category
General[1]	Proposal summary
General[1]	Gatekeeper permission
General[1]	Application forms
General[1] and health[2]	Research design
Health[2]	Health research
Health[2]	Health specific questions
General[1]	Population and sampling
General[1]	Data collection instruments
General[1]	Data collection methods
General[1]	Procedures for consent
General[1]	Vulnerable participants
Health[2]	Health related activities
General[1]	Participant incentives
General[1]	Human participant risk category
General[1]	Human Participant Ethics Considerations
General[1]	Human Participant Conflict of Interest
General[1]	Data management plan
General[1]	Protection of Personal Information

[1]Applies to other forms of research and is not specific to health research.

[2]Specific to health-related research.

There are five health research committees in Gauteng, one for each of the five districts in the province [10]. Health researchers should be aware of this as each health district follows unique approval processes. The health research ethics application process has been documented on https://profmoosa.com/ [11]. It must be noted however that the documented process refers to the University of the Witwatersrand Health Research Ethics Committee and is not necessarily generalized to other universities. **Table 2** provides a summary of the research ethics application process that the first author intended to use. The steps presented are a mixture of the processes described by the sources noted above as well as from the author's previous research ethics applications.

Table 2. Anticipated ethics application steps

Step	Description
1	Create ethics application via the University's research ethics portal [12]
2	Register the research project with the National Health Research Database [10]
3	Upload proof of National Health Research Database registration to the University's research ethics portal
4	Request letter of support from gatekeepers (hospital or department managers)
5	Receive final approval from National Health Research Database
6	Receive final approval from the University
7	Receive final approval from the relevant gatekeepers

The actual research ethics and gatekeeper application process presented in Supplement [13] was a 38-step process. The research method of this paper is discussed in the next section.

3 Research method

Pragmatism has been described as a research paradigm that renegotiates reality [14]. Three methodological fundamentals of pragmatic research are presented below [15]:

- Emphasis on actionable knowledge – the results of the research should display elements of practicality and should be actionable,
- Inquiry as an experiential process – people will question how problems are solved. Reference in this case is made to the solving of organizational problems. It must accordingly be noted that though this research does not focus on any one research ethics committee, from an organizational perspective, it does consider research ethics as being bound by research ethics committees or organizations, and
- Recognition of the interconnectedness of experience, knowing and acting – this contributes to the contextualization of problems and how they can be solved.

The PhD was presented as a case study in conjunction with the anticipated ethical clearance and gatekeeper permission processes. The actual process that was followed is presented in Supplement [13]. A content analysis of three governing ethics policy documents, presented in **Table 3** was conducted to identify the definitions and rules that regulate healthcare research. Using three cycles of coding, underlying themes

within these documents were identified and related to the case study. Once all the data were analyzed, recommendations were identified and presented.

Table 3. Three ethics governance policy documents selected for analysis.

Document name	Rationale for analysis
Policy on Research Ethics [16]	As a PhD student, the first author had to become familiar with the research ethics policies and guidelines prior to initiating the ethics review process. It is safe to assume that researchers (including students) should be familiar with their institutions research ethics policies through consulting their institution's documentation. The policy document provides the definitions for research which includes healthcare research.
Ethics in Health Research [17]	The Policy on Research Ethics document provides guidelines on ethical research practices, but it refers the reader to the National Health Act for further detail. Since this document provides detail aimed at healthcare research it was deemed necessary to analyze the document.
National Health Act, 61 of 2003 [18]	The Policy on Research Ethics and Ethics in Health Research documents refer to the National Health Act document for definitions and further information. This document focusses on the overall healthcare system and refers to healthcare research.

The content of the three policy documents were analyzed using ATLAS.ti version 23.4.0.29360. This version of ATLAS.ti is integrated into OpenAI and can perform coding on the uploaded documents using AI [19–21]. The integration of AI coding in qualitative analysis has shown an increase [22] however the stand-alone use of AI for coding is still novel. To ensure rigor in this research, the three documents were analyzed using three cycles of coding with a hybrid approach of AI and human-centered coding. This hybrid approach was followed in a related study which analyzed twenty-one documents using three cycles of coding done by AI and the researchers [23]. The three cycles of coding led to the identification of themes which were then related to the research ethics processes described earlier. Recommendations relating to Digital Health research were then formulated and presented.

4 Results

The policy documents were first investigated to determine whether Digital Health research was clearly defined. It was found that policy documents provided a hierarchical definition where Digital Health research which was not precisely defined. The definitions are illustrated in **Fig. 1**.

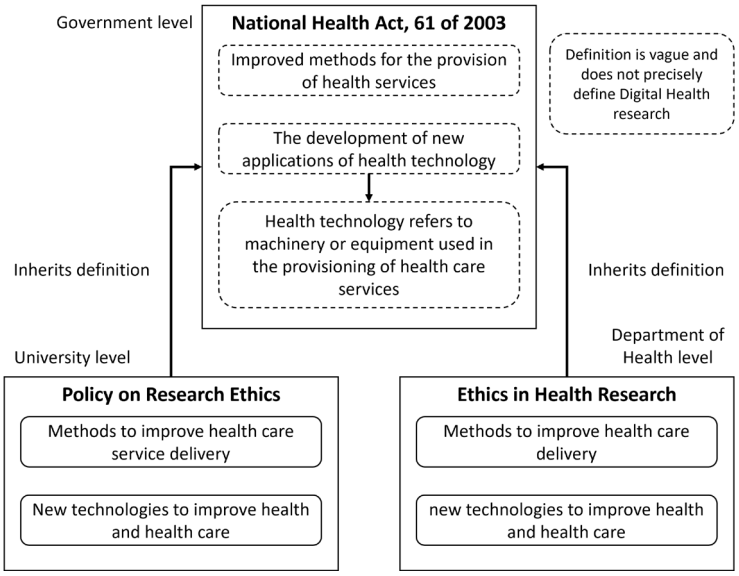

Fig. 1. Health research definitions according to the relevant policy documents

A qualitative content analysis of the three essential research ethics policy documents was done using three cycles of coding. The first coding cycle adopted a hybrid approach of human-centered and AI coding (ATLAS.ti integration into OpenAI). The human-centered coding revealed 73 codes and the AI coding revealed 122 codes. In the second coding cycle, the human-centered codes were grouped into 11 code groups and the AI generated codes were grouped into 9 code groups. The 9 AI code groups formed a subset of the human-centered code groups resulting in a total of 11 code groups. The 11 code groups were then associated with each other during the third cycle of coding revealing the relationships illustrated in **Fig. 2**.

	Healthcare service delivery	Definition of healthcare research	Committees	Data handling	Medical research	Non human participants	Research ethics	Research planning	Rights of participants	Vulnerable groups
Academic Integrity	promotes	is bound by	is verified by	requires	is related to	is related to	is verified by	requires	protects	protects
Healthcare service delivery		is indirectly related to	is indirectly related to	is indirectly related to	is promoted by	is indirectly related to	is indirectly related to	is indirectly related to	is related to	is related to
Definition of healthcare research			is promoted by	is indirectly related to	defines	is indirectly related to	regulates	influences	protects	protects
Committees				require	regulate	is related to	verify	is indirectly related to	protects	protects
Data handling					is required by	is related to	is required by	is part of	is related to	is related to
Medical research						is related to	is regulated by	requires	must protect	must protect
Non human participants							are protected by	are protected by	are protected by	are protected by
Research ethics								requires	must protect	must protect
Research planning									must include	must include
Rights of participants										includes

Fig. 2. The relationships identified amongst the 11 code groups.

Fig. 2 illustrates the 55 identified relationships. The relationships highlighted in orange and yellow were regarded as subtle relationships and were consequently omitted from the analysis. Once the 18 subtle relationships were removed, 37 relationships remained. The remaining relationships and code groups were then associated with each other using the ATLAS.ti network function. This is illustrated in Supplement [24].

The four themes were then derived using a combination of the code group relationships illustrated in Supplement [24] and the associations of the quotations, codes and code groups presented in Supplement [25]. AI-derived and human-derived quotations were carefully considered.

As presented in Supplement [24], the four themes are described below:

- *Participant rights* – Participants have rights that need to be protected by researchers. Rights can include their safety and anonymity. Since participant groups can include vulnerable groups (minors, women and people living with disabilities), researchers need to take extra precautions to ensure that the rights of vulnerable groups must not be violated. It must however be noted that individuals who are deemed to be part of a particular vulnerable group may not see themselves as being vulnerable. This theme applies to all forms of research that involve human or non-human participants.
- *Healthcare research* – This can consist of medical research which can involve clinical trials and the use of medication or medical equipment. The provisioning of healthcare services is also included in healthcare research however its definition is not clearly articulated. This theme applies to healthcare research and may apply to Digital Health. This will be argued in the next section.
- *Research integrity* – This theme, which applies to all forms of research, refers to the integrity of the researcher as well as the governing committees. Researchers must be adequately qualified to conduct the research and must uphold the ethical standards as set out by the relevant committees.
- *Research preparation* – Prior to the initiation of the research, the researcher must present a detailed proposal to the relevant committee. This proposal must include details regarding research ethics (this is a broad topic which includes how human and non-human participants will be interacted with) and how the research data will be handled. This theme applies to all forms of research.

The four themes were then associated with each other and with the concept of Digital Health research. The results of this together with the recommendations are presented in the next section.

5 Discussion

Digital Health research, which is at the intersection of information systems research and medical or health research, requires researchers in South Africa to follow the health-related research ethics application process instead of the standard processes that would apply to information systems research. It was anticipated by the first author that the ethics and gatekeeper application process would follow seven steps to obtain full approval however this proved to be a 38-step process with elements of process entanglement which left the first author often uncertain about how to continue with the application.

The Policy on Research Ethics contains six definitions for Health research, four of which are purely medical with the remaining two being potential options for Digital Health research projects. The fourth definition from the Policy on Research Ethics states "methods to improve health care service delivery" however the document provides no specifics on the definition of "methods to improve health care service delivery" [16]. The Ethics in Health Research contain the same options but also does not provide a thorough definition of health care service delivery [17]. The National Health Act, 61 of 2003 refers to "improved methods for the provision of health services".

The Policy on Research Ethics provides another definition which states "new technologies to improve health and health care". The definition for technologies is provided by the National Health Act, 61 of 2003 which defines it as "machinery or equipment that is used in the provision of health services…".

The definitions of Health research provided by the guiding documents do not clearly define Digital Health research, which as mentioned earlier focusses on digital systems and does not necessarily include healthcare technologies. Three out of the four themes identified in this research refer to principles that are applicable to all types of research, with healthcare research being the only theme that refers to healthcare service delivery. **Fig. 3** illustrates the relationships between the four themes and Digital Health research. It can be observed that Digital Health research must follow the same ethical standards as healthcare research, yet it defers from medical research, does not meet all the criteria of healthcare research and does not necessarily relate to healthcare service delivery.

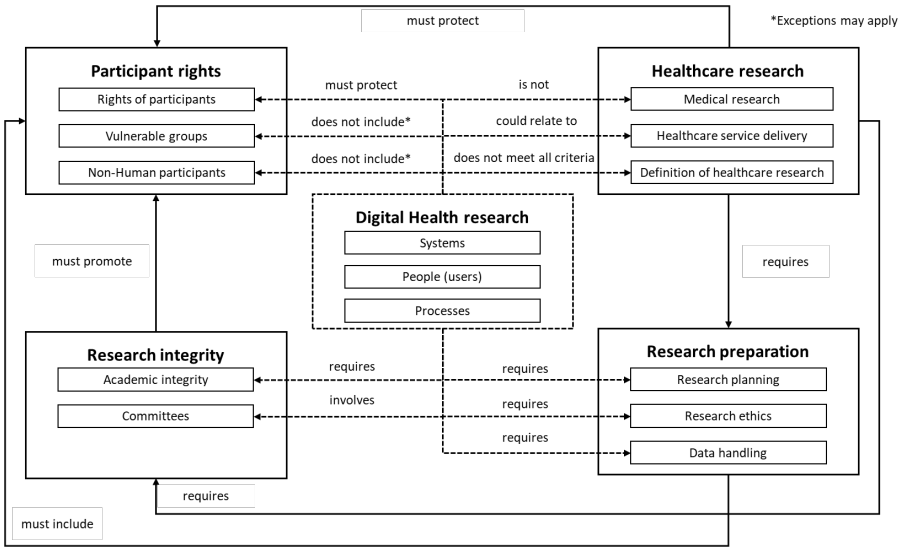

Fig. 3. The relationships amongst the four themes and Digital Health research

The first author was expected to select health research for a PhD study on Digital Health, on the online ethics application. All the answers relating to health research were however recorded as "No". If you consider the lack of a precise definition for Digital Health research, the deficiency of clear linkage between Digital Health research and Health research, the absence of patient interaction, the absence of medical data, the exclusive use of online interviews and the responses to the health research questions on the online ethics application, it is unclear why the research was categorized as health research.

Admittedly, the research sought to investigate healthcare related processes from healthcare workers, however the minimal risk of the study should have resulted in a different ethics application route. Research ethics committees and policy makers should therefore take note of the following recommendations.

- Due to the proliferation of Digital Health research projects, Digital Health research should be clearly defined in all necessary ethics policy documents. A possible definition could be "Digital Health research is a subdiscipline of Information systems research and is concerned with the healthcare context. Digital Health research considers the structure, layout, and integration of healthcare related information. Human participants and technology may be involved in the research however should medical tests, medical data or medical procedures be involved then the research may be classified as Health related.",
- The ethics application process for Digital Health research should be posted on the appropriate University's website so that researchers can plan their application process accordingly,
- The definition of Digital Health research should make clear use of parameters such as whether there will be patient interaction or the use of sensitive data,

- The ethics application systems should display elements of fluidity in the response to questions:
  - If the researcher answers "No" to all Health research questions, then the risk level should be automatically downgraded, or
  - If the researcher states that all interactions will take place online, then this reduces the risks associated with a researcher visiting a healthcare facility and should result in a downgrading of the risk level,
- Based on the scenarios described above, research ethics committees should be empowered with the ability to allow a researcher to avoid the district level approvals and be allowed to obtain direct gatekeeper permission based on the recalculated risk category, and
- A decision chart such as the one illustrated in **Fig. 4** should be used by Research Ethics Committees to guide them on how to differentiate between Health related research and Digital Health research. The decision chart was discussed with two ethics chairs who saw merit in this approach to differentiating between the research types.

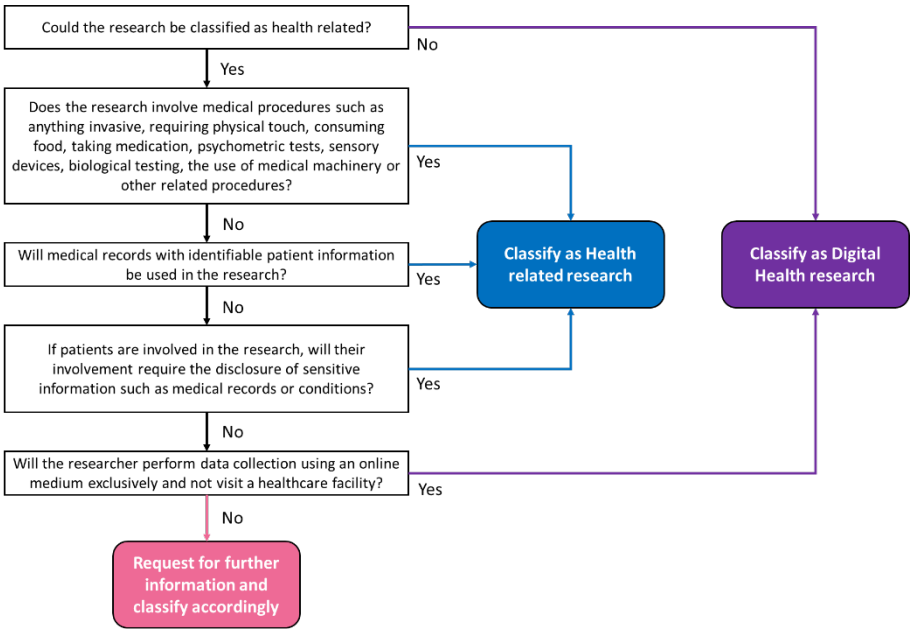

Fig. 4. Decision chart to guide research ethics committees.

The decision chart illustrated in **Fig. 4** is an initial version. Further research will be conducted to convert the decision chart into a more comprehensive decision tree containing more permutations. Research ethics committees have important responsibilities to research participants, communities and to the researchers. The generalized inclusion of all Digital Health research projects into the health research category, however, results in unnecessary processes being followed for otherwise low risk re-

search. This not only lengthens the ethics application process but also puts a strain on the committees and gatekeepers themselves. Digital Health research should therefore be reclassified or be included in a unique research category to promote the optimization of the research ethics processes.

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Learners' Perception of IoT in the Mauritian Higher Education

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Abstract. The Internet of Things (IoT) connects multiple devices that collect and transmit data without human intervention into one and provides a digital network connection that can change everything, anytime, from any tool. Hence, IoT continues to strengthen its imperative place in the progress and growth of society. The use of IoT in the higher education in Mauritius will bring new opportunities and possibilities for the improvement of both teaching and learning process and HEIs' infrastructure. This research, therefore, evaluates the learner's perceptions on the adoption of IoT in the field of higher education in Mauritius which will bring new opportunities and possibilities for the improvement of both teaching and learning process and HEIs' infrastructure. The sample selection in this study used a convenience random sampling technique and the target population was reduced to public HEIs' in Mauritius. The research yielded 280 usable responses and analysis of descriptive statistics, frequencies, and chi-square test were conducted to address the research objective. The findings showed how the adoption of IoT can help academics and learners influence technologies' benefits to improve learning and academic performance. The results revealed that the learners have a positive attitude towards IoT. Learners have a digital mindset and hence the adoption intention behavior on IoT was positively accepted. The study contributes to the future adoption of IoT by universities from both a theoretical and practical standpoint.

Keywords: Internet of Things, Learners' perception, higher education institution.

1 Introduction

Nowadays, information technology is touching various industries (Financial Services, Entertainment, Telecommunication, Healthcare and Manufacturing) and the Higher Education Institutions (HEIs) should not be left behind. By connecting devices (like personal computers, tablets, laptops, smartphones, etc.) to the inter-net, the Internet of Things (IoT) is in the attempt of changing several routines of our lives and the use of intelligent association between individuals and things to share information and experience (Mahbub, 2020). In 1999, Kevin Ashton was the first to use the term IoT. An international network connects things and offers information to the internet to share with the surroundings (Gowrishankar et al.,2015). IoT can transmit the resources over the system automatically without individual or computer devices interaction.

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According to Aldowah et al. (2017; 2015), the education sector is also one of the industries that is to be impacted by the quick expansion and application of IoT. It upholds intelligence and autonomy and is ubiquitous (Kahlert, 2016). At present, several HEIs have understood the significance of adopting IoT into daily teaching and learning activities (Madakam et al., 2015). The impacts of the COVID- 19 pandemic are clearly visible on the education sector and hence, e-learning, or remote virtual learning has turned out to be popular practice in several universities. An upswing in the regular application of IoT enables HEIs to enhance the efficacy of teaching and learning, stimulating comfortable and speedy access to information. Learners can connect with their lecturers, friends, and professionals from the entire world in their classrooms with such network devices (Ralhan, 2017).

Thus, a regular traditional classroom can change to a smart class that can be coordinated with e-learning. Adopting IoT to higher education encourages an excellent association and cooperation among learners, with their lecturers, or lecturers with lecturers through the devices that are connected. IoT offers learners enhanced access to the whole world (teaching facilities, learning materials, educational performance results and communication networks). For academics, it also offers an innovative way of relating to learners and enhances the skill to gauge learners' learning performance immediately, providing a more personalized educational experience.

This study supports the importance of the IoT and recognizes that such technology has turned out to be an important part of daily teaching and learning. Besides, it also attempts to describe the usefulness and applications of IoT in the future higher education of Mauritius. This research evaluates the learner's perceptions in adopting IoT in the field of higher education in Mauritius.

1.1 Aim of the Study

The COVID-19 pandemic was a unique global health disaster that has had far-reaching economic and social implications. The rapid changes in education due to the COVID-19 pandemic have necessitated the integration of ICT in higher education. However, the education system is just getting started with IoT and its full impact is not yet fully comprehended. Therefore, it has become more important to provide an affluent learning experience, improve operational efficiency, and to gain real-time, actionable insight into student performance. Hence, the adoption of IoT in the higher education in Mauritius will bring new opportunities and possibilities for the improvement of both teaching and learning process and HEIs' infrastructure. The adoption of IoT will strive to radically transform the way HEIs function and improve learner education. This research attempts to evaluate the learner's perceptions to adopt IoT in the field of higher education in Mauritius. Besides, it also strives to describe the usefulness and applications of IoT in the future higher education of Mauritius.

2 IoT in the Higher Education Sector

IoT is evolving rapidly and progressively turning into an emergent area that produces enthusiasm and apprehension in the world (Ning and Hu, 2012). Many suggestions indicate that IoT will transform many industries, including the education sector, especially HEIs. The possibility of interacting with everything that is connected to the Internet provides learners with a vast pool of information anytime and anywhere. According to Demski (2012) IoT improves and expands the critical skills of learners. It develops, intensifies, and speeds up the learning process of the learners since it also links the learners with the physical world. In the traditional learning process, pen and pencil were imperative tools to acquire knowledge. However, today IoT has initiated opportunities for education (Demski, 2012). Smartphone is also a latest progress in the mobile technologies field, which offers an easy access to learning (Kim *et al.,* 2017). According to Enrique (2010), IoT comprises of various tools that are comfortable to use with internet, which provides an easy way to connect with their peers and lecturers. Therefore, IoT will bring adequate changes and improvements to the HEIs. According to Tianbo (2012), IoT will be responsible for the adjustments in educational technology, restructuring of education, revolutions in teaching, transformations in learning, modernizations of campus, resources for teaching and learning developments, etc.

Zhiqiang and Junming (2011) pointed out that the progress in IoT lies on these three features: learners' progressive appraisal, incorporation of existing teaching and learning platforms and the introduction of an educational middleware. These changes will offer improved accessibility for learners and present a more effective teaching process for the academics. The flow in connected devices and technology means that instructors and professors can focus on the actual learning that is more useful to the students rather than perform the routine task.

2.1 Digital Campus

The setting of the HEIs can completely transform by applying IoT based smart amenities in the establishments. It can enhance the whole services by employing IoT technologies. Digital campus is corroborating, along with smart learning, smart classrooms, and smart laboratories. A smart digital campus may involve the following IoT supported:

- Smart E-learning
- Smart Classroom
- Smart Labs
- Sensors for Notes Sharing
- Sensors used for Mobiles Devices
- Hotspot for Campus
- Smart Parking and lighting
- Smart Inventory
- Smart Students Tracking
- Resource centers

Smart Learning. The traditional learning environment involves two main groups in the learning process, the academics who teach and the learners who study. The typical teaching and learning processes involved both groups to remain in same place and at the same time, which necessitates both groups to make themselves accessible is a challenge (Abuarqoub et al., 2017). A smart learning environment causes a complete continuous learning procedure. The three main dimensions of learning resources to contribute and exchange information are learning groups, learning subjects, and lastly the learning facilities.

Smart Classroom. On the other hand, a Smart Classroom is an intellectual class that incorporates innovative teaching and learning approaches with up-to-date pedagogy along with growing technologies. This concept's system requisite is necessary to guarantee committed communications among learners and academics to virtually cooperate by taking care of the course objectives (Bargaoui and Bdiwi, 2015). Smart classroom concepts have confirmed to encourage internet-based learning, like e-learning, m-learning, and various distance education methods. A smart classroom is a place for learners to learn and perform simultaneously. To accomplish collaborative tasks, academics assemble learners to work in small clusters. In this manner, learners are assisted to help each other to manage with hard challenges. In the traditional classroom design, all the learners in front of their desk follow their lecturer's presentation.

Smart Laboratories. In the Smart Laboratory, to retain energy, IoT is used to assign suitable time and selects complete advantage of the available resources. For example, all the lights spontaneously switch on as arriving in the lab, and each learner will be allocated a precise apparatus. The procedure traces the use of the labs and initiates more labs when it is needed. It is also able to close any unused computers. In addition, air conditioners are switched on automatically when the temperatures are out of range.

2.2 Perceived benefits of the Internet of Things

According to Alhogail (2018), the adoption of new technology, including IoT, is based on the perceived benefits. The latter refers to the extent to which a person considers that with the IoT technology their study/work/life performance would be enhanced (Hsu and Lin, 2016). Therefore, perceived advantages of IoT services advocates that people will consider that the facilities will allow them to improve all their daily tasks either professionally or personally connected. Consequently, it develops the quality of living, allows more relaxation time etc., largely, a better study life balance. In a study conducted by Lee *et al.* (2011), it was found that comparative benefit turns meaningful and positive when adopting technology. Therefore, perceived advantages of the IoT technology must be supported to attain positive implementation of the IoT.

2.3 Benefits of utilizing IoT

There are numerous advantages of applying IoT. They include a rise in efficiency, growth in productivity and increase in flexibility. A study conducted by Kranz (2017)

revealed that IoT produces better efficiency and productivity. On the other hand, the study done by Schimek (2016) established that IoT increases in flexibility.

3.0 Methodology

This study assesses how students in Mauritius view IoT in higher education. Moreover, it also aims to outline the benefits and potential uses of IoT in the future higher education sector of Mauritius. It employs a quantitative approach based on a survey carried out among learners in the public HEIs in Mauritius. The survey included students from University of Mauritius (UoM), University of Technology (UTM), Open University of Mauritius (OUM), and Université des Mascareignes (UdM), with 386 respondents selected through random sampling.

The data collection tool was created according to the research aim and relevant literature. The questionnaire comprised of two parts where the first part included the five questions to examine the demographic profiles of the learners. On the other hand, the second part of the questionnaire expanded on the dependent variable and the independent variables, which were to be measured in the survey. The 5 demographic questions examined the information such as gender, age, education qualification, and years of experience in using IoT products and services and frequency of use. A combination of 5-point Likert scale and dichotomous items were aimed to provide quantitative data in the second part.

The Google form survey was distributed using a convenience random sampling technique to first-year students in various fields of study. Care was taken to make the sample as representative as possible and the ethical and confidentiality considerations were strictly respected during data collection and respondents have been enlightened about their anonymity concerning confidential data. After conducting a meticulous data screening process, only 280 out of the completed questionnaires were deemed suitable for analysis due to the exclusion of unengaged responses and multivariate outliers.

The information gathered is subsequently examined with the Statistical Packages for Social Sciences (SPSS) software for descriptive analysis, incorporating frequency, standard deviation, and mean calculations. Next, a Pearson Chi-square test was carried out to evaluate the link between students' views on IoT and their opinion on whether IoT should be integrated into higher education. Inferential statistics were employed to draw conclusions about a certain unknown factor of the population based on the sample taken from it.

4.0 Results and Discussion

To assess the internal consistency of the factors the reliability test was conducted. The factors were reasonably reliable as they met the threshold of 0.70 as suggested by Hair *et al.* (2016). The Cronbach's alpha values were 0.739 (IoT and Education), 0.783 (IoT and Learning), 0.891 (Application of IoT in Classroom) and 0.887 (Perception of IoT).

4.1 Descriptive analysis

According to Quintana *et al. (*2017), a descriptive analysis is the critical transformation of information applied to illustrate the fundamental characteristics of data gathered. In this study, the analytical method that is performed to evaluate and understand the basic characteristics of the data is covered by the demographic profile of respondents; and (2) descriptive analysis of data collected. From the demographic data analysis, the results show some distinctive characteristics of the HEIs where 94.12% of the respondents are between 18 to 25 years old. According to Hauk, Huffmeier and Krumm (2018), as age increases technology acceptance decreases, and this is largely due to perceived ease of use therefore this was considered an advantage, as young learners tend to interact with technology significantly more than people who are older.

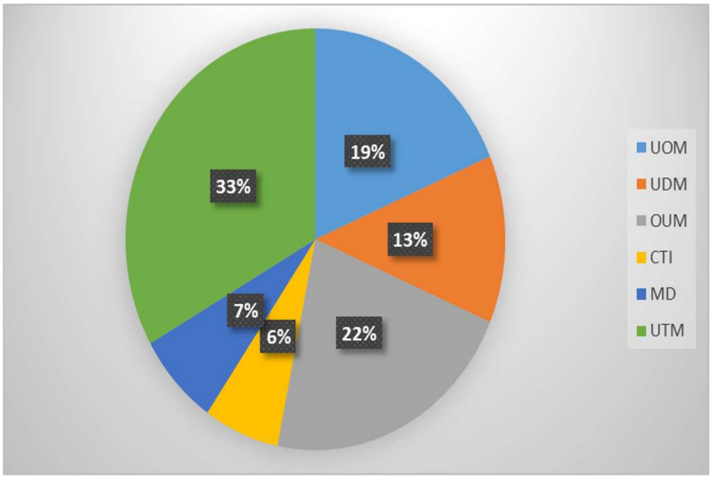

Fig. 1. HEIs in Mauritius

This showed that most students were of the millennial group and therefore they had a more open behavior in grasping and appreciating new technologies such as the IoT products and services. Therefore, they were familiar with IoT products and services, which directed them to provide enhanced insight into their perception of IoT. Additionally, most of the learners of the HEIs were not exposed to the IoT products and services regardless of the area of expertise they had; most of the learners were studying in Management courses. The study was dominated by Undergraduate learners representing 89% whereas the Post Graduate learners were represented by 11%. This indicated that knowledge about how IoT influences the daily living style of the learners in general, which was a good sign in terms of enablement and promoting cutting edge technologies to the younger generations. 100% of the respondents had internet access and they all get access to the internet through mobile data and Wi-Fi as compared to the internet café.

72% of the learners very often go online whereas only 28% often go online. It is worth noting that all the respondents had a Smartphone, 63% a laptop, 27% a computer, 1% PDA, 6% iPad, 11% iPhone and 36% had a tablet as shown on Fig 2. Today high-

tech products as well as services are no longer seen as a privilege to or limited to only the computer literate user group with a strong technology background but more like a common trend and activity in anyone's daily life. This finding will help policy makers in their vision to become a highly digitalize and innovative nation soon.

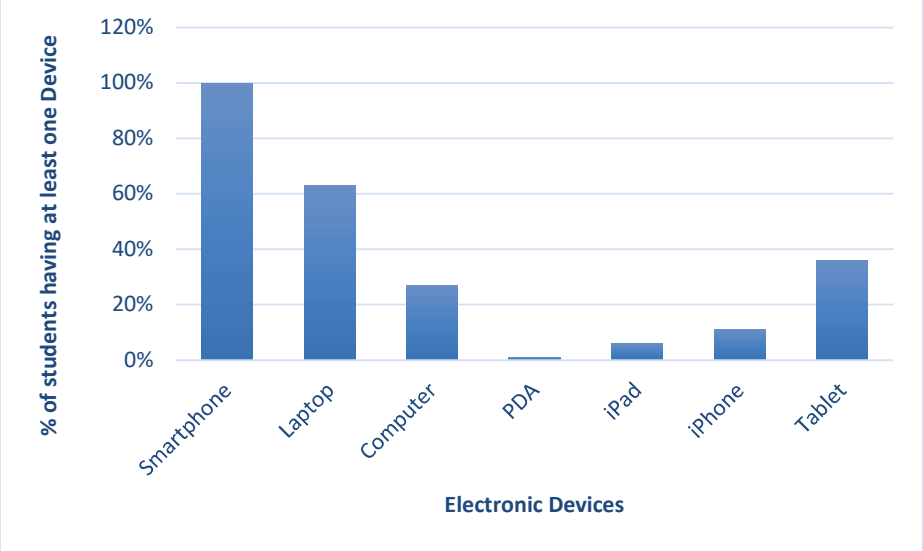

Fig 2. Electronic devices possessed and mostly used to access the internet.

4.2 Learners' Perspectives

Students were questioned with respect to their perception towards the use of IoT in their learning and on Campus. They were also asked about their opinions on various aspects of IoT, the difficulties they faced and what they appreciated about the adoption of IoT. Four scales namely IoT and Education, IoT and Learning, Application of IoT on campus, and Perception of IoT to measure the opinions of the learners.

IoT and Education. An interesting point is the use of IoT as an educational tool as shown in Table 1 below. The mean score for these prioritized themes that a university should attend when adopting an IoT environment; with a mean score of 3.97 students have a very strong perception about the adoption of IoT that their lecturers would have better opportunities for course planning. The students perceived that With IoT, teaching should be more creative (mean = 4.03, SD = 0.861); IoT will make teaching more interesting for them (mean = 3.86, SD = 0.966); and they would prefer the use IoT technology in the classroom (mean = 3.93, SD = 1.057). As Enrique (2010) had pointed out IoT provides an easy way for the learners to connect with their peers and lecturers for learning. The greater the learners' perception of engagement, the greater their

perception of learning. Similarly, Galina and Yankova (2020) asserted that IoT enabled lecturers to boost their operational efficiency in an online learning environment.

Table 1. IoT and Education.

	N	Min	Max	Mean	Std. Deviation
With IoT, my lecturers would have better opportunities for course planning.	280	1	5	3.97	0.835
With IoT, teaching should be more creative.	280	1	5	4.03	0.861
With IoT, teaching would be more interesting for me.	280	1	5	3.86	0.966
I would prefer the use IoT technology in the classroom.	280	1	5	3.93	1.057

IoT and Learning. The level of IoT and learning was assessed with a 4-item scale anchored on a 5-point rating system (1 = strongly disagree and 5 = strongly agree). As summarized in Table 2, most participants agreed that IoT would improve their learning. For, 46.1% agreed that with IoT they will feel more motivated and confident while 40% and 43.6% of the learners felt more focus and inspired to learn using IoT devices/ applications. With IoT, 36.8% believed that their teaching can be adapted on an individual level. Participants had a positive opinion about the use of IoT devices/applications would improve their learning. Even Hanan Aldowah, *et al*., (2017) considered that IoT had the ability to increase the learning experience by providing for real-time and actionable insights into student performance.

Table 2. IoT and Learning.

	Strongly Disagree	**Disagree**	**Neutral**	**Agree**	**Strongly Agree**
	Frequency (Percentage)				
With IoT I will feel more motivated.	2.1	1.4	22.5	46.1	27.9
With IoT my focus would be improved.	1.4	3.6	21.1	40	33.9
With IoT, teaching would be more inspiring me.	3.6	5.0	21.8	43.6	26.1

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
	Frequency (Percentage)				
With IoT, teaching can be adapted on an individual level.	4.6	6.4	17.5	36.8	34.6

Applications of IoT on campus. Table 3 further illustrates that the participants agreed that the use of IoT devices in the classroom/lab would help them improve teaching and learning. It was observed that students overall had a positive attitude toward the IoT application in their classroom/lab. According to Aldowah et al., (2015), allow learners to study at their own pace and have same learning experience in classrooms. Galina and Yankova (2020) expressed that IoT can support classroom instruction by improving learning settings, methods, and techniques, enhancing learning resources, raising management efficiency, and saving management costs. Furthermore, some of the HEIs have classes are so big that taking learners' attendance turns out to be a discouraging task. Hence, it is unlikely to expect lecturers to remember every learner's name and this is why they call out each name one by one. According to Credé et al. (2010), keeping track of attendance is useful because learners' participation is essential in some courses and attendance is a predictor for class success. Using IoT technology, academics can monitor students' presence in an efficient manner. Lecturers can monitor their student's attendance at the same time be able to find out their overall engagement with academics also. The lecturers can use this data to track their own teaching performance, with the assumption that learners who regularly attend class are expected to do better. IoT devices can be used to search for students in the classroom and notify parents if they are not present (Bagheri and Movahed, 2016).

Table 3. IoT in the Classroom/Lab.

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
	Frequency (Percentage)				
My lecturers will be able to monitor attendance.	3.2	3.6	19.3	32.9	41.1
Monitor attention with eye-tracking during tests	7.1	13.9	22.9	25	31.1

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
	Frequency (Percentage)				
Monitor air quality in the classroom/lab.	0.4	0.7	10.4	33.2	55.4
Personal feedback from lecturers	0.7	0.4	10	30	58.9

Perception of IoT. On average most of the participants agreed that IoT products improve their ability to perform their daily activities and tasks efficiently, support them to save time, provide access to information quicker, perceived positively the adoption of IoT in their institutions. 40.4% of the participants strongly agreed that IoT products and applications are trustworthy, while 42.9% believed that they provide reliable information that can used for learning and count on their university to protect their information (66.4%). Similarly, 47.1% admitted that IoT products and applications improved their performance of daily activities and tasks and 49.3% like using the IoT products and applications. 48.2% learners' overall attitude towards using IoT products and applications in the higher education was favorable where 44.3% perceived benefits related positively to the adoption of IoT.

Today, there is a growing demand for HEIs to digitize their content and activities and adapt their methods to allow academic and students to work and learn efficiently in a digital environment. Therefore, a well-designed physical campus, completely integrating technology, is fundamental for building the brand of digital university by enhancing the student experience, and providing the appropriate settings and facilities for teaching, learning and research. According to Porter and Sherwin (2013), it encourages, favors, and boosts lifelong learning.

Table 4. Perception of the use of IoT in education.

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
	Frequency (Percentage)				
IoT products and applications are trustworthy.	2.5	2.5	22.1	32.5	40.4
IoT products and applications provide reliable information.	2.1	3.9	21.8	29.3	42.9
I think that IoT products and applications will improve my	1.4	5.4	8.9	37.1	47.1

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
	Frequency (Percentage)				
performance of daily activities and tasks.					
I like using IoT products and applications	1.8	2.5	9.3	37.1	49.3
I can count on my university to protect my information.	0	1.4	7.9	24.3	66.4
Overall, my attitude towards using IoT products and applications in the higher education is favorable.	2.1	3.2	11.1	35.4	48.2
Perceived Benefits relates positively to the adoption of IoT.	2.1	8.2	7.9	37.5	44.3

A chi-square test was performed to determine the association between students' perception of IoT and whether they felt that IoT should be incorporated into their education, learning and classroom. The results of the test were significant, $\chi 2(143, N=280) = 2186.42$, $p<.001$ indicating a significant association between the students' perception of IoT and whether IoT should be incorporated into their education. $\chi 2(91, N=280) = 997.534$, $p<.001$ indicating a significant association between the students' perception of IoT and whether IoT should be incorporated into their learning. $\chi 2(91, N=280) = 980.968$, $p<.001$ indicating a significant association between the students' perception of IoT and whether IoT should be incorporated into their classroom. Similarly, the Likelihood Ratio test was significant, $\chi 2(143, N=280) = 1058.85$, $p<.001$; $\chi 2(91, N=280) = 964.053$, $p<.001$; $\chi 2(91, N=280) = 663.995$, $p<.001$, supporting the presence of a significant relationship.

5.0 Conclusion

According to Gabriela (2013), IoT in education creates a new environment that supports the acquisition of knowledge in a new, and efficient manner consistent with the learners' needs and expectation. Smart campus can attract more students to learn with the integration of the technology in education. The use of computers, laptops, Smart phones, tablets, white boards, and many other tools are becoming an easy way of communications that save our time in doing different things nowadays. Administrative process much easier with the use of IoT, which makes administrative cost cheaper and more efficiently.

This study provides an insight on the perception learners have on the application and use of IoT in the HEIs, not as a substitute for existing on-campus education, but as a

complement to it. According to the existing literature and analysis of data presented above, IoT integration can bring variations to the methods students learn, and therefore adapt the already existing learning models. This means that academics may have to adjust their basic theory to technological improvements and consequently approve new features that can exist in the prevailing learning concepts. The integration of IoT in the higher education sector of Mauritius will enhance self-directed learning, and at the same time, academics will have less administrative tasks hence additional time for their learners. Even, Sari *et al.* (2017) argued about how the IoT integration can eventually create possible smart campus infrastructure in an HEI.

A requirement and essential element for teaching using IoT products is that the teaching materials need to exist online. Students can obtain feedback on their activities, probably automatic and in actual time. Moreover, by giving information regarding their performances, academics can get evidence of knowledge gained and help them prepare enhanced teaching materials in the future. Besides, IoT allows students to have learning material in accordance with their educational needs. As argued above, such materials are designed in line with the learners' learning needs and is available online and is spread through network since this is how IoT works.

Finally, it can be concluded that IoT has great ability to bring important values to the higher education sector in Mauritius by motivating and engaging the learners and academics. The purpose of this study was to find out the perception of IoT in higher education and the students believed that IoT does increase their speed of learning.

Most learners are currently using IoT in some way or the other, but they are not conscious of it. It is therefore important to create an awareness of IoT applications to inform the learners of the benefits from IoT without putting themselves at risk. Hence, academics and management should be considered to take part in this study for achieve the overall respondents. Therefore, the future work will be to focus on IoT adoption in higher education.

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Empowering Business Analysts for Society 5.0 and Industry 5.0: Strengthening Capabilities for Digital Transformation in South Africa

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Abstract. Business Analysts (BAs) play a crucial role in driving innovation and facilitating data-driven decision-making, particularly in the evolving technological landscape of Society 5.0 and Industry 5.0. This paper presents a practical framework for enhancing the skills of BAs to meet the demands of these new paradigms. The framework focuses on developing BAs' skills in data science, data analytics, and research and development, which are crucial for thriving in the Information economy of the Fourth Industrial Revolution. Presented at the IIBA-SA 2023 Summit, the framework illustrated the use of Data Science and Analytics tools and techniques to transform customer experience. Specifically, the framework employs Sentiment Analysis to understand customer feedback and Principal Component Analysis (PCA) to extract features impacting customer dissatisfaction, thereby identifying opportunities for digital transformation. Additionally, the framework introduced the Design Science Research (DSR) method, offering BAs a systematic and rigorous approach to problem-solving, innovation, and knowledge creation. Despite being a new concept for many participants, the framework generated high interest and curiosity. This paper underscores the importance of empowering BAs to adapt to the evolving technological landscape, enabling them to contribute significantly to problem-solving and knowledge creation in South Africa.

Keywords: Society 5.0, Industry 5.0, Design Science Research, IIBA, Business Analysts, Digital Transformation, IIBA Southern Africa Summit.

1 Introduction

Technological innovations are changing the way enterprises operate, fostering the emergence of new sectors, new business models, new kinds of firms, new specialist jobs [1], and presenting new competitive advantages through automation [2], robotic process automation [3], and data-driven decision making [4]. These advancements require a focus on developing a variety of specific competencies and interdisciplinary skill sets crucial for stabilizing the market and facilitating smooth transitions between different professions [5]. This is especially true in the software engineering domain. The very innovations that software developers create are reshaping their work. As IT

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professionals construct new automation tools for various industries, their work processes and tasks are substantially influenced by the technologies they develop [6].

The European Commission embraced the technologies of the Fourth Industrial Revolution (4IR) by developing a framework to leverage these technologies in serving Society 5.0 objectives [7, 8], while the Japanese cabinet also leveraged the technologies to establish a sustainable Industry 5.0 model where production aligns with environmental boundaries and prioritize the well-being of industry workers [9, 10]. However, in the South African context, the technological innovations of the 4IR are considered a mix of blessings and curses [2]. Upon becoming the president of South Africa, President Cyril Ramaphosa's integration of the Fourth Industrial Revolution (4IR) into the national economic strategy sparked debate over its alignment with neoliberal principles like those promoted by the World Economic Forum (WEF). Concerns were expressed regarding its potential to address unemployment. This reservation is undisputable given that South Africa faces a substantial skills deficit, primarily attributed to deficiencies in its education system, which restricts the availability of managers, researchers, and workers essential for the 4IR [11]. The impacts of Industry 4.0 and Society 5.0 on work and employment are expected to be complex, possibly exacerbating inequality by decreasing the demand for low-skilled workers. Additionally, there are challenges related to inadequate infrastructure quality, indicative of governance weaknesses and state capture. The country's track record in policy development and implementation, particularly across different departments, is poor, leading to significant delays in cybersecurity and data protection [2, 11-13].

The principles of Society 5.0 and Industry 5.0 can be applied in South Africa to address economic and societal challenges through innovation and digital transformation. In this context, BAs are key players in driving innovation, facilitating data-driven decision-making, and ensuring organizations remain competitive in an ever-evolving technological landscape. BAs are responsible for identifying business problems, analyzing their root causes, and ensuring they are resolved with the most feasible and valuable solutions (Weilbach et al., 2023). Although business analysis has evolved significantly, transitioning from the waterfall methodologies era to the agile approach and becoming more crucial for businesses, the specialization is laced with a plethora of challenges. One of which is that the boundaries of the domain are getting blurred as professionals in different roles increasingly integrate business analysis tasks into their daily responsibilities [14], resulting in the perception of business analysis as a diminishing practice with decreasing importance and potential for extinction. Furthermore, the BA role is often ambiguous, lacking a universally accepted definition, and is considered one of the least defined roles in IT [14-16].

The adoption of 4IR technologies in South Africa will amplify existing challenges in business analysis, given the region's economic and political landscape. Mukozho and Seymour [17] assert that the onset of the Fourth Industrial Revolution has raised significant questions about the future skills required in the business analysis profession. The study noted a lack of studies in the digital age that systematically track the evolution of necessary skills over time and stress the importance of further empirical research to inform the Business Analysis Body of Knowledge (BABOK) and to help practitioners ensure that their skills align with the demands of the Fourth Industrial Revolution.

Therefore, this study aims to present a practical framework as a guideline to enhance the competencies of BAs to meet the demands of the futuristic society and industry by leveraging the technologies of the Fourth Industrial Revolution. This study answers the research question, “What specific competencies are required for Business Analysts (BAs) to effectively navigate and excel in futuristic society and industry, leveraging the technologies of the Fourth Industrial Revolution?”.

The paper is structured as follows: Section 2 outlines the study's background, presenting the interplay between Society 5.0 and Industry 5.0 and the role of a Business Analyst (BA) in the evolving technological landscape. Section 3 describes the research methodology; detailing the framework and the justification for its constructs, while Section 4 presents the data analysis focusing on the skills and capabilities required by a BA for Society 5.0 and Industry 5.0. The implication of the studies for the BA practice is discussed in Section 5. Finally, Section 6 provides the paper's conclusion.

2 Background

In the backdrop of Industry 5.0 and the emergence of Society 5.0, there is a growing recognition of the need for businesses to adapt to new technological advancements and societal shifts. The interplay between these concepts drives significant changes in the workforce, requiring businesses to rethink their strategies and upskill their employees to remain competitive. This paper explores the role of Business Analysts (BAs) in the evolving technological landscape, highlighting the need to acquire new capabilities to thrive in Industry 5.0 and Society 5.0. The framework presented in this paper aims to facilitate the understanding of the competencies needed to excel in the information economy, ensuring that BAs can effectively contribute to their organization's success in the digital transformation era.

2.1 Society 5.0 and Industry 5.0

The Japanese cabinet in 2016 embarked on the journey towards an intelligent, ultimately smart society under Japanese Prime Minister Shino Abe [18]. The hallmark of Society 5.0 is the vision to create a high degree of merging between cyberspace and physical space and balance economic progress with the resolution of social issues by offering products and services that specifically target various underlying needs, irrespective of location, age, gender, or language [19]. Leveraging technologies of the Fourth Industrial Revolution (4IR), such as AI, Big data, and 5G, Society 5.0 projects a futuristic, human-centered, highly intelligent, and efficient society driven by scientific and technological innovation [20-22]. The core value of Society 5.0 is to build a human-centered, super-smart, and lean society, ensuring a comfortable and sustainable future for all [20].

Industry 4.0; a German initiative in 2011 from a high-tech strategy project [23] is hinged on the previous three industrial revolutions to enable production systems, represented by Cyber-Physical Production Systems (CPPS), autonomously make informed decisions by communicating and collaborating in real-time with "manufacturing things," leading to the flexible production of high-quality personalized products with mass efficiency [8]. The concept of Industry 5.0 evolved from its predecessor –

Industry 4.0, and started to gain traction in 2017 [9]. However, in 2021, the European Commission officially endorsed the Industry 5.0 concept following deliberations among stakeholders from research and technology organizations and funding agencies across Europe [7, 8]. Industry 5.0 acknowledges the potential of the industries to serve societal objectives beyond mere job creation and economic growth. It aims to establish a sustainable model where production aligns with environmental limits and prioritizes the well-being of industry workers. This approach supplements the current Industry 4.0 framework by emphasizing the role of research and innovation in transitioning to a European industry that is sustainable, human-centric, and resilient [7]. Atkin to Society 5.0, the core values of Industry 5.0 include human centricity by putting the needs and interests of people at the heart of production processes, sustainability, re-using, re-purposing, and recycling natural resources to reduce waste and environmental impact and resilience, developing a higher degree of robustness in industrial production for agile response to geo-political shifts and natural emergencies [20].

2.2 The Interplay between Society 5.0 and Industry 5.0

The interplay between the futuristic society and industry is such that the industrial revolution will drive societal development, while societal transformation will propel the next industrial revolution [18, 20]. This is because both concepts share similar opportunities and challenges. As analyzed by Huang et al. (2022), the integration of cyberspace and physical space, known as Human-Cyber-Physical Systems (HCPS), is a critical technology for both Society 5.0 and Industry 5.0. This involves human involvement in decision-making processes and interaction loops. Additionally, the development of the Human Digital Twin (HDT) is crucial for modeling and simulating human behavior in these systems. Another common area is Greentelligent Manufacturing (GIM), which focuses on using AI for sustainable and green manufacturing practices. Human-Robot Collaboration (HRC) is also a key research area, aiming to merge human and machine intelligence to enhance innovation in manufacturing. The transformation brought by Society 5.0 and Industry 5.0 will impact future jobs and workers. While automation may lead to job losses in some areas, new roles like data analysts and automated guided vehicle coordinators will emerge [5, 6, 20]. Hence, stakeholders need to adapt to these changes efficiently to create smart, resilient manufacturing systems that predict, respond to, and recover from disruptions.

2.3 The Evolving Role of a BA in Society 5.0 and Industry 5.0

In the era of Society 5.0 and Industry 5.0, characterized by rapid technological advancements and the integration of digital technologies into every aspect of society, the role of Business Analysts (BAs) has become increasingly vital. Business Analysis allows organizations to express their needs and reasons for change and design and define solutions that can provide value to the organization. A business analyst (BA) is responsible for identifying business problems, analyzing their root causes, and ensuring that problems are resolved with the most efficient solutions that deliver value to all stakeholders [1]. BAs are key players in driving innovation, facilitating data-driven decision-making, and ensuring that organizations remain competitive. The International Institute of Business Analysis (IIBA) defines business analysis as the process of facilitating

change within an organization by identifying needs and proposing solutions that provide value to stakeholders [24]. The evolving landscape of industry and society leads to increased automation of physical and repetitive tasks, enhancing the utilization of solutions integrating digital technologies to gain data-driven insight into the customers' pain points [2, 3, 25]. However, this shift also creates opportunities for new jobs that require different skills and competencies [20].

The Industrial Development Think Tank has expressed concerns about South Africa's ability to adapt to this revolution [26]. Cross-national comparisons and national studies often indicate that the country's technological capability and level of digitalization are inadequate [27, 28]. The fear of increased joblessness and inequality looms with the advent of the Fourth Industrial Revolution (4IR). The McKinsey Global Institute has projected substantial workforce disruption by 2030, with automation potentially displacing up to 13% of current work activities in South Africa. The impact of the 4IR on jobs is a pressing concern, highlighting the need for proactive measures to address potential job displacement and mitigate inequality in the face of advancing technologies [29]. A study conducted to explore public opinion on the impact of technologies of the 4IR on South Africa reported that technology aversion is high among South Africans as workers who are vulnerable to being displaced by automation and artificial intelligence will be more hostile to technological change in society [2]. Technology aversion presents as a barrier to technology adoption to solve the economic and societal challenges in South Africa. This threat is even more pronounced for BAs, given the context of the problems experienced already in the domain.

Despite this context, the role of BAs is not about to go extinct any time soon, given the fact that organizations need them to enhance their understanding of the utilization of solutions integrating digital technologies, their value delivery, and a deeper insight into customers' viewpoints. However, to meet the demands of Society 5.0 and Industry 5.0 and the ability to solve real-world problems, BAs must possess unique competencies beyond traditional business analysis. Society 5.0 represents a human-centered society that leverages technological advancements, such as artificial intelligence (AI) and big data, to address societal challenges and improve the quality of life. Industry 5.0, on the other hand, focuses on the integration of cyber-physical systems into manufacturing processes to create smart factories and drive efficiency. In this context, the Fourth Industrial Revolution has put the future skills of the profession into question [17]. The role of BAs has expanded to include an understanding of data analytics, machine learning, and other advanced technologies to drive the identification of the use cases of the 4IR technologies in improving business processes. As inferred from Kusiak [30], in the context of smart manufacturing, BAs must possess the skills to analyze large datasets, identify patterns and trends, and make data-driven recommendations to drive business growth and innovation. The literature emphasizes the importance of collaboration and interdisciplinary skills for BAs in Society 5.0 and Industry 5.0. As organizations become more interconnected and reliant on technology, BAs must be able to collaborate effectively with data scientists, engineers, and other stakeholders to translate business requirements into technical solutions [17].

This paper presents a practical framework as a guideline to enhance the competencies of BAs to meet the demands of the futuristic society and industry by leveraging the

technologies of the Fourth Industrial Revolution. The framework focuses on equipping BAs with the tools and techniques necessary to excel in a data-driven environment. The implementation of this framework marks a significant step forward in preparing BAs in Southern Africa for the challenges and opportunities presented by Society 5.0 and Industry 5.0. Organizations can remain agile, innovative, and competitive in the global marketplace by empowering BAs with the skills they need to thrive in this new era.

3 Method

3.1 The BA 4IR Competency Framework

The BA 4IR Competency framework is designed to guide BAs in acquiring the competencies necessary to thrive in leveraging technologies of the 4IR in the era of Society 5.0 and Industry 5.0. This framework was introduced at the 2023 BA Summit Southern Africa as a practical approach to addressing the evolving role of BAs in a rapidly changing technological landscape. Hinging on the comparison between the goal, value, organization and technology dimensions of Society 5.0 and Industry 5.0 drawn by Huang, Wang [20] depicted in Fig. 1 and the work of Ellitan [31] on competing in the era of industrial revolution 4.0 and Society 5.0., we map out the competencies required by business analysts to continue facilitating change within an organization by identifying needs and proposing solutions that provide value to stakeholders in the context of the evolving technological landscape for the futuristic society and industry. From the different dimensions identified by Huang et al., we select themes relevant to the competencies of a BA and map out the requirements and the skills needed to provide value for each theme.

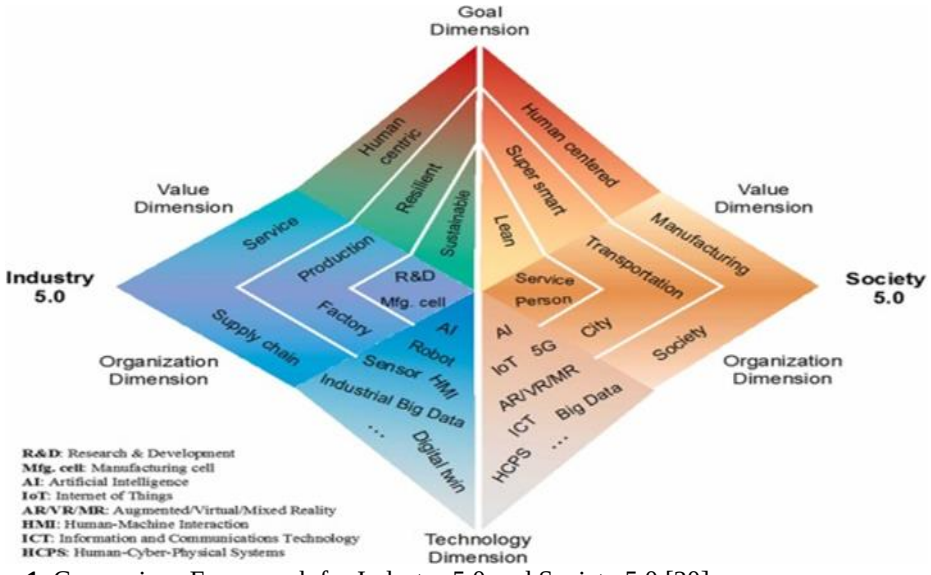

Fig. 1. Comparison Framework for Industry 5.0 and Society 5.0 [20]

3.2 Key Dimensions of the BA 4IR Competency Framework

1. **Human Literacy:** From the goal dimension of Industry 5.0 and Society 5.0 (Figure 1), BAs need to be human-centric. They should place humans at the center of design, decision-making, and problem-solving processes to create more intuitive, effective, and meaningful products, services, and systems for people. This competency includes empathy coupled with excellent communication skills to convey ideas effectively. Collaboration skills are also essential for working with diverse stakeholders, adaptability is critical in rapidly changing environments, and ethical awareness is necessary to make responsible decisions. Notably, data literacy is vital for acquiring human literacy to analyze and interpret data to drive meaningful insights. Possessing these skills will enable BAs to contribute to a human-centered approach, which is a central goal of Industry 5.0 and Society 5.0, ensuring that the needs of individuals are prioritized in technological and societal advancements. Adopting the principle of democratization of technology is expedient in achieving human literacy.

2. **Research Literacy:** Industry 5.0 and Society 5.0 places research and development at the forefront of manufacturing. Therefore, BAs need to acquire competencies in research and development. It is important to note that research in Information Technology (IT) differs from other disciplines, such as Social Sciences. It is a discipline that requires practical solutions to complex problems and a problem-oriented research methodology. The Design Science Research (DSR) is one such methodology. This methodology, popular in various disciplines, including information systems, computer science, engineering, and business, focuses on creating and evaluating artifacts like models, methods, and tools to solve complex problems and improve processes. Using the DSR methodology as a guide for Research in IT, BAs must possess capabilities to identify problems, analyze data, propose innovative solutions, and evaluate their effectiveness. Proficiency in relevant tools and techniques for data analysis, modeling, and visualization is crucial, as is effective communication to convey complex ideas and solutions or tell data stories to stakeholders. Additionally, collaboration skills are essential for working with cross-functional teams to develop and implement solutions. Being adaptable to changing technologies and methodologies and having a strong ethical awareness are key competencies needed to succeed in this role in the futuristic industry and society. By applying design science research methods, a business analyst can document best practices in business analysis, contribute to knowledge creation, and provide valuable insights for future generations of business analysts.

3. **Process and Product Literacy:** The organization dimension of Industry 5.0 and Society 5.0 (figure 1) requires the BAs to add value in industrial contexts of manufacturing cells, production factories, and supply chains and as a service person in the societal context. In this context, BAs must possess process literacy

- an understanding of industrial processes and supply chain operations, and product literacy - the knowledge of products and services within the industry. To acquire these competencies, however, BAs need technological literacy to gain familiarity with emerging technologies like AI and IoT, analytical skills for data analysis and process improvement, problem-solving skills to address challenges and propose solutions, communication skills for effective stakeholder engagement; adaptability to respond to industry and societal changes; collaboration skills, for working in diverse teams; ethical awareness, to understand and align with societal values; and a commitment to continuous learning, to stay updated with industry trends. These skills are essential for Business Analysts to navigate the complexities of Industry 5.0 and Society 5.0, contributing to organizational success and societal advancement.

4. **Technology and Data Literacy:** The technology dimension enables the goal, value, and organization dimensions of Industry 5.0 and Society 5.0 (Figure 1). The core values of Industry 5.0 and Society 5.0 are to put the needs and interests of people at the heart of production processes and ensure sustainability by reusing, re-purposing, and recycling natural resources to reduce waste and environmental impact. Also, resilience for developing a higher degree of robustness in industrial production for agile response to geo-political shifts and natural emergencies and to leverage technologies of the 4IR, such as AI, Big data, and 5G, for a futuristic, human-centered, highly intelligent, and efficient society driven by scientific and technological innovation ensuring a comfortable and sustainable future for all require BAs to acquire competency in technology and data. BAs should understand emerging technologies such as AI, big data, digital twins, and IoT, and how these technologies can be applied to solve problems in the industry and society. BAs should also be proficient in analyzing large datasets, have a good understanding of technical concepts related to software development, systems integration, and data management, and be adept at identifying problems and proposing solutions. Effective communication skills are crucial for explaining complex technical concepts to non-technical stakeholders and collaborating with cross-functional teams. Additionally, BAs should be adaptable and willing to continuously update their skills and be aware of ethical issues related to data privacy, security, and bias in AI algorithms. Developing these skills can help them contribute to the digital transformation of industries and societies in the futuristic industry and society.

While the IIBA Business Analysis Competency Model outlines the domain, technical, business, and soft skills required to fulfill the BA role [32], The 4IR demands new and faster ways of work, including a more technical-focused BA, as the technological complexity increases [17]. Based on the BA competency requirements for the goals, values, organization, and technology dimensions of Society 5.0 and Industry 5.0, Fig. 2 presents a network diagram emphasizing the flows within the BA 4IR

Competency framework. It helps locate dominant contributions to an overall flow between the competencies required per dimension.

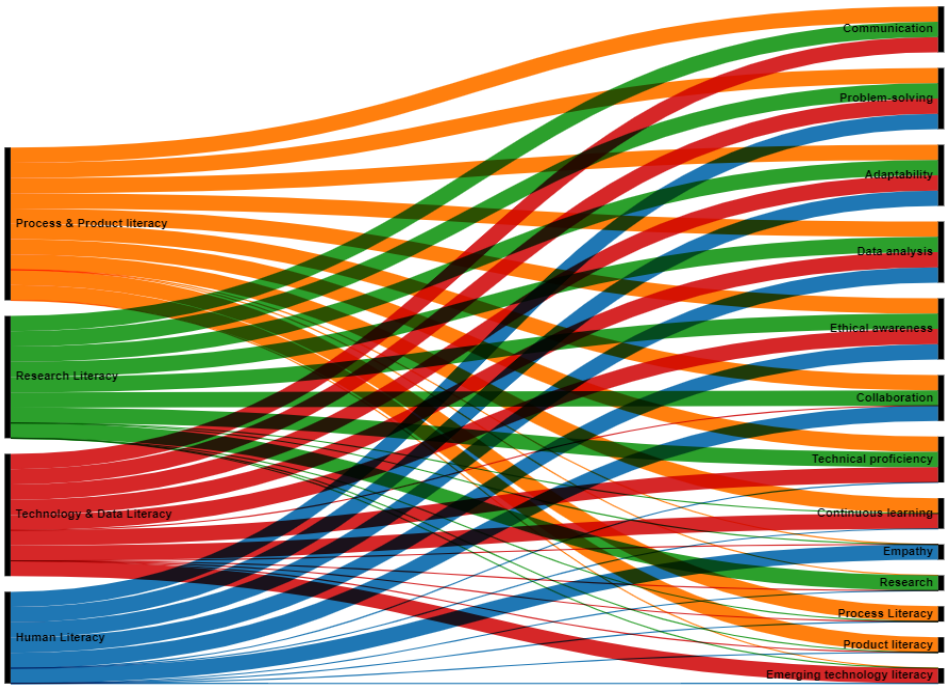

Fig. 2. Network Diagram of Dimension to Competency Flow of the BA 4IR Competency Framework.

4 Competency Mapping to the BABOK Knowledge Areas

The Business Analysis Core Concept Model™ (BACCM™) is a foundational framework within business analysis, offering a universal understanding of the discipline's fundamental principles. This model encapsulates the essence of business analysis, providing clarity and coherence to practitioners irrespective of their background, industry, methodology, or organizational hierarchy. Comprising six key terms, the BACCM facilitates meaningful discussions among business analysts and fosters a shared understanding of business analysis concepts and their interrelationships [32].

The BACCM identifies six core concepts: Change, Need, Solution, Stakeholder, Value, and Context. These concepts are regarded as fundamental ideas essential to business analysis. Each concept holds equal importance, forming a comprehensive framework for conducting business analysis activities. While the BACCM provides a conceptual framework for understanding business analysis principles, the BA Knowledge Areas provide a practical framework for applying those principles in real-world business analysis projects. Together, they offer a comprehensive and integrated approach to business analysis, combining conceptual understanding with practical application.

The Knowledge areas represent areas of specific business analysis expertise that encompass several tasks, including business analysis planning and monitoring, elicitation and collaboration, requirements life cycle management, strategy analysis, requirements analysis and design definition, and solution analysis. These knowledge areas are mapped to the competencies identified in the BA 4IR Competency Framework depicted in Table 1.

The Business Analysis Planning and Monitoring (BAPM) knowledge area (KA) requires competencies to enhance the effectiveness of planning and monitoring activities. For example, adaptability, collaboration, and empathy ensure that stakeholder engagement is productive and inclusive. Problem-solving, data analysis, and research competencies are necessary in assessing risks and selecting appropriate techniques and tools for BA activities. Continuous learning and emerging technology literacy help keep business analysis practices current. Ethical awareness ensures that all these activities are conducted transparently. Process and product literacy provide context for informed decisions during planning and monitoring.

In the Elicitation and Collaboration KA, competencies like problem-solving, adaptability, collaboration, technical proficiency, and research support Bas' preparation for elicitation. Data analysis, process literacy, and emerging technology literacy help explore and identify relevant information. Ethical awareness, empathy, technical proficiency, and data analysis ensure the accuracy and consistency of the information elicited. Product literacy, continuous learning, and technical proficiency promote a shared understanding of BA information, while collaboration, empathy, and ethical awareness ensure stakeholder participation in business analysis activities.

Table 1. 4IR BA Competency to BABOK Knowledge Area Mapping

Competencies	**BAPM KA**	**Elicitation and Collaboration KA**	**Requirements Life Cycle Management KA**	**Strategy Analysis KA**	**Requirements Analysis and Design Definition KA**	**Solution Evaluation KA**
Problem-Solving	X	X	X	X	X	X
Adaptability	X	X	X	X	X	X
Data Analysis	X	X	X	X	X	X
Ethical Awareness	X	X	X	X	X	X
Collaboration	X	X	X	X	X	X
Technical Proficiency		X	X	X	X	X
Continuous Learning	X	X	X	X	X	X
Empathy	X	X	X	X	X	X
Research	X	X	X	X	X	X

Process Literacy	X	X	X	X	X	X
Product Literacy	X	X	X	X	X	X
Emerging Technology Literacy	X	X	X	X	X	X

Requirements Life Cycle Management focuses on managing requirements from inception to retirement. competencies like problem-solving, technical proficiency, research, and product literacy are crucial for tracing requirements. Data analysis, technical proficiency, emerging technology literacy, product literacy, and continuous learning ensure accuracy and consistency during the entire requirements life cycle. Collaboration, empathy, problem-solving, and product literacy help rank requirements in the order of relative importance. Adaptability, problem-solving, ethical awareness, and technical proficiency evaluate proposed changes, while collaboration, empathy, ethical awareness, and process literacy ensure clear communication.

The Strategy Analysis KA involves understanding business contexts, defining change strategy, and aligning proposed solutions with business goals. Data analysis, research, technical proficiency, process literacy, and empathy enable an understanding of the need for change and its impacts. Collaboration, problem-solving, ethical awareness, and continuous learning help guide the development of the change strategy. Data analysis, technical proficiency, emerging technology literacy, and ethical awareness are essential for understanding the consequences of internal and external forces on an enterprise. Problem-solving, adaptability, collaboration, product literacy, process literacy, and continuous learning help develop and assess alternative approaches to change.

Requirements Analysis and Design Definition KA organizes, specifies, models requirements, and identifies potential design options. Technical proficiency, research, process proficiency, and data analysis competencies are required to analyze, synthesize, and refine elicitation results into requirements and designs. Problem-solving, collaboration, and technical proficiency ensure that requirements meet quality standards. Empathy, collaboration, ethical awareness, and adaptability align requirements with business needs. Product proficiency, process proficiency, technical proficiency, and emerging technology literacy ensure that requirements achieve pre-stated objectives. Research, continuous learning, problem-solving, adaptability, and data analysis identify improvement opportunities and design options. Collaboration, empathy, ethical awareness, and emerging technology literacy estimate value and select an appropriate design alternative.

Solution Evaluation KA assesses the performance of a solution in use to ensure it meets the business requirements and delivers the expected business value. Data analysis, technical proficiency, and research competencies help BAs define performance measures and evaluate the effectiveness of a solution. Problem-solving, data analysis, and process literacy provide insights into performance concerning value. Empathy, technical proficiency, and ethical awareness determine internal factors restricting value realization. Collaboration, product, and emerging technology literacy are needed to determine external factors restricting value realization. Problem-solving, collaboration,

adaptability, and continuous learning help understand the differences between potential and actual value and recommend actions.

5 Framework Implementation

The Business Analysis Summit Southern Africa - the annual flagship event for BAs in Southern Africa gathers a delegate of over 300 Business Analysts and their employers to discuss how their role can provide business value and support strategic change. The call for paper for the summit themed “Elevate. Empower. Excel: Inspiring the Future of Business Analysis opined that achieving growth necessitates venturing beyond one's comfort zone. It involves continually seeking new knowledge, understanding, and moments of insight with a mindset of the willingness to teach others and to learn from them, along with a constant desire to progress. This attitude is stated to fuel personal development and enable individuals to maintain their focus and excel in their field. The 2023 event was a three-day event consisting of four tracks. Track one was themed on the sustainability mindset, while tracks two, three, and four were themed on leadership and collaboration, business analysis mastery, and maturing your practice, respectively.

As academics, both authors have been actively involved in the IIBA-SA community since 2018, while the first author has a background in BA consultancy. They both play key roles in developing learning and development strategies for BAs in the KwaZulu-Natal region of South Africa. Their efforts include conducting university workshops to educate students on best practices in business analysis and organizing and facilitating fortnightly Tools and Techniques sessions for BAs in all provinces in South Africa. These sessions provide practicing BAs in South Africa with an hour of training from global speakers, enhancing their knowledge of tools and techniques in the field. The authors' experience bridging academia and industry has inspired them to present at the conference's third track.

The 50-minute presentation to the BA Summit delegates was titled "Master of Business Analysis (MBA) – Growing your Imprint for the NextGen Business Analysts”. The presentation hinged on the fact that the role of a business analyst becomes increasingly vital as the world transitions into Industry 5.0 and Society 5.0. Industry 5.0 emphasizes human-cobot collaboration, and Society 5.0 envisions a seamless fusion of cyberspace and physical space, both driving innovation across all sectors. This evolution underscores the need for intensified partnerships between academia and business analysts to co-create value through evidence-based practices and collaborative problem-solving. They emphasize the need for enhanced data science and data analytic skills as key to evolved business analysis practice and modeled data-driven problem-solving using Sentiment Analysis to identify customer pain points via negative sentiments, Principal Component analysis to reduce the dimensionality of the features extracted from the negative sentiments and identifying problems worth solving, and finally the use of Design Science Research for research and development in IT and knowledge creation by publishing business analysis artifacts, creating evidence of best

practices in business analysis for the next generation of BAS and ensuring the sustainability of the practice.

Both speakers delivered their presentations simultaneously, employing a case study approach to enhance delegates' ability to relate the discussed problems and solutions to their work contexts. The presentation sparked significant interest and curiosity among delegates regarding the concepts of Society 5.0 and Industry 5.0, which is evident from the substantial number of questions received at the session's conclusion. Additionally, ten delegates patiently waited in a queue to engage with the authors and seek further insights. The IIBA SA leadership also met with the authors and expressed alignment with the sentiments shared by previous scholars [2, 11-13] on the blurring of professional lines, the diminishing importance of the practice, and the increasing importance of digital transformation programs for BAs. The community leadership adopted Data Analytics as the overarching theme for the first quarter of 2024 and re-invited the authors to present the same topic for the first tools and techniques session in 2024.

The framework will be further evangelized through training programs, workshops, and mentoring sessions for BAs and BA managers. By presenting a practical approach to address the evolving role of BAs in a rapidly changing technological landscape BAs with the necessary skills and competencies, the framework aims to enhance their professional development and ensure they remain relevant in the digital age.

6 Conclusion

The presented framework offers a practical approach to enhance the skills of Business Analysts (BAs) in Southern Africa, aligning them with the demands of Society 5.0 and Industry 5.0. BAs play a crucial role in driving innovation and facilitating data-driven decision-making in a rapidly evolving technological landscape. The framework, introduced at the IIBA-SA 2023 Summit, emphasizes the importance of continuous learning among BAs to adapt to the changing environment effectively.

By modeling collaborative problem-solving using factorial analysis, sentiment analysis, and the design science research (DSR) method, the framework provides BAs with the tools to solve real-world business problems and publish their solutions in academic journals. Despite being new concepts for many participants, the framework was positively received, highlighting the need for BAs to evolve their skills to meet future challenges. While the IIBA Core Competencies Model describes the competencies required from BAs to perform in their roles, these competencies are not specifically mapped to the contexts of the 4IR or the potentials of technologies from the era to ensure the agility of industries and sustainability of societies and enhance the lives of individuals. Therefore, this study mapped the six BA Knowledge Areas to the competencies required for a BA to thrive in the context of the 4IR to create value in the futuristic industry and society.

The framework is key to empowering BAs in Southern Africa to contribute effectively to organizational success and produce documented evidence of best practices in the domain. By mapping the necessary competencies BAs require to provide value in

the futuristic society and industry, the framework aims to ensure that BAs remain relevant and valuable in the era of Society 5.0 and Industry 5.0, ultimately driving innovation and facilitating sustainable growth in their region.

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Digital Transformation Readiness for Online Teaching and Learning in Higher Education: Academics Perspectives

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Abstract. The purpose of this research are to (a) examine the academics' perceptions toward digital transformation readiness, more specifically academics' preparedness to embrace a digital culture, (b) investigate if there are significant differences in these perceptions based on the academics' demographic variables such as gender, age, academic status and academic discipline, and (c) investigate the factors that affect academics' digital transformation readiness and their significant role in determining student engagement and intention to use technology. A structured questionnaire was designed in Google Forms covering the perceptions of the teachers regarding blended teaching and learning. The study collected 165 responses through online surveys from academics of a public university in Mauritius. The data was analyzed descriptively and inferentially to validate the model and perform regression analysis and ANOVA. The findings showed that only digital acceptance and digital competence influenced the intention to use digital technology amongst academics.

Keywords: Digital transformation readiness, academics, higher education, Mauritius

1. Introduction

There has been an unprecedented development of new technologies, especially following the outbreak of the COVID-19 pandemic. This situation has presented a significant challenge and transformation in the higher education (HE) landscape, compelling HE institutions (HEIs) to seek alternative teaching and learning methods through digital learning environments, serving as substitutes for traditional face-to-face learning [1,2,3].The adaptation of educators to online teaching holds the potential to foster innovation within academic institutions, thereby elevating the quality of online teaching and learning (OTL). It is argued that proper integration of technology-supported services and appropriate digital tools successfully promotes the transformation of traditional teaching and learning environments with new digital methods to work better in the digital era [4, 5]. However, the advent of digital transformation has posed challenges for academics, as the transition to real-time online teaching proved to be difficult for some [6]. Notably, some educators lacked proficiency in the use of the required technology, resulting in digital gaps among them [7]. Consequently, it becomes imperative to investigate whether experience with this method contributes to positive attitudes and adoption in the realm of digital readiness for real-time online teaching.

Past studies have sought to understand the factors that influence educators' use of technology in education, including multiple factors such as lack of institutional digital support and infrastructure, digital competences, digital culture, digital training, curriculum, virtual collaboration, time management and student digital engagement [8,9,10]. implementation of digital technologies in various aspects of academic teaching and learning, and digital readiness and acceptance are important factors to better understand the diverse engagement experiences of academics, whose perspectives are critical to any transformation in higher education [3, 10]. Academics have expressed concerns not only regarding their pedagogical competency in effectively navigating online platforms but also about their perceived lack of control over the virtual learning environment and their inability to use the non-verbal communication medium during real-time online teaching [11]. Furthermore, an engaging in online teaching-learning environment necessitates key elements such as a robust network, internet access, a smart device or computer, a welcoming atmosphere, and proficiency in technical skills [12]. Despite these challenges in higher education, universities are trying to leverage digital technologies adoption.

Understanding academics' perceptions of digital readiness for online teaching and learning is an important and popular research topic. The literature extensively discusses frameworks for digital readiness in online teaching and learning [3,9,10,13]. However, it is apparent that digital readiness varies among faculty due to cultural, institutional, and contextual factors, suggesting that educators' readiness for online teaching will also

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differ accordingly. Hence, there is an urgent need for further research into academics' perception and receptivity of such initiatives.

The purpose of this study is to examine whether online teaching has induced shifts in academics' attitudes concerning their digital transformation readiness for online teaching and learning. The objectives of this research are to (a) examine the academics' perceptions toward digital readiness, more specifically academics' preparedness to embrace a digital culture, and (b) investigate if there are significant differences in these perceptions based on the academics' demographics such as gender, age, and teaching disciplines.

2. Literature Review

The transition to online education in higher education institutions during the pandemic was to reduce human contact in the classrooms as well as across the universities to lower the spread of the COVID-19 [14]. Online classrooms include virtual platforms like Learning Management System (LMS), Zoom, online discussion boards and platforms, pre-recorded video lectures, Microsoft Teams, Google Meet, provide opportunities for discussion with students in real time interaction [15]. Digital transformation has revolutionalized the learning processes of not only students, but that of educators [16]. Academics were forced to embrace novel approaches to online teaching, which required their adaptation to modern technologies where their digital readiness was essential to improve the learning experience [17, 18]. Moreover, the attitude of teachers towards technology plays a significant role in defining their digital readiness and the appropriate utilization of technology [14, 19].

Digital readiness refers to preparedness to use digital technologies for academic engagement [20]. According to these authors, digital readiness consists of technology-related knowledge, skills, attitudes, and competencies necessary for using digital technologies effectively in higher education. Digital readiness encompasses a range of abilities and competencies, including technology and computing, information science, and media and communication skills. Digital readiness has been measured in several ways, mostly amongst students. For example, student digital readiness was assessed by the use of the Digital Readiness for Academic Engagement questionnaire (DRAE) across five dimensions (i) digital tool application, (ii) information sharing behavior, (iii) information seeking skills, (iv) digital media awareness, (v) digital application usage. Student readiness was assessed in universities using a scale based on the following components [21] (i) equipment availability where students indicated if they had access to various digital devices, including personal computers, mobile phones, scanners, printers, and internet; (ii) experiences with e-learning tools where students explained their experiences with different e-learning tools made available by the university such as online lecture notes, lecture recordings, use of digital media in courses, online modules, online communication and collaboration platforms, online-tests, (iii) self-reported digital learning skills where students' were required to assess self-reported skills for digital learning, where two dimensions of the DRAE questionnaire developed was used [20].

Another factor which is important to consider in digital transformation in higher education is the digital competence of academics. Digital competence can be defined as "the confident, critical and responsible use of the technologies from the society of information for work, entertainment and education" [22]. Being digitally competent involves a combination of personal attitude, technical skills, and an elevated level of multiliteracy [23]. Multiliteracy refers to the ability to access, identify, understand, create, communicate, and compute data from various sources [24, 25]. Different authors have identified a range of literacies that result in digital competency and these components have been summarized by [26]: (i) *Information skills* which is the ability to search for, access, manage, understand, secure and classify content found across different formats on the web [27]; (ii) *Content creation or media skills* which involves creating and editing new content in different formats (e.g., audio, video, text) by integrating available information[25,28]; (iii) *Communication skills* which is the effective use of communication via digital tools with other online platform members and the capacity to collaborate and network [29, 30]; (iv) *Ethical skills* which is the ability to understand the rules relating to content ownership and relations with other participants in the network [31, 32]; (v) *Problem solving skills* which is the ability to address and resolve problems generated by the use of digital tools [28, 33]; (vi) *Technical skills* which is the ability to access the technical knowledge to use digital tools [34, 35]; (vii) Strategic skills which is the ability to apply the aforementioned digital skills to make personal and professional progress [27,36].

Digital technology has become an integral part of higher education with the potential to enhance teaching and learning processes and predict increased student engagement [37, 38]. In recent years, scholars, practitioners, and policymakers have devoted significant attention to understanding and measuring student engagement.

Influential works, including Astin's (1999) theory of involvement [39], Fredricks, Blumenfeld, and Paris's (2004) delineation of the three dimensions of student engagement (behavioral, emotional, cognitive) [40], and sociocultural theories by Kahu (2013) [41] and Kahu and Nelson (2018) [42], have contributed to research on the multidimensional concept of student engagement. Student engagement has been shown to improve achievement, persistence, and retention [43]. Conversely, disengagement has been linked to negative student learning outcomes and cognitive development [44] and serves as a predictor of student dropout in both secondary schools and higher education [45]. The multifaceted and intricate student engagement construct has also been referred to as a 'meta-construct' by some scholars [40, 41]. Student engagement has been examined using different dimensions [44]; (i) active participation and involvement in learning and university life (e.g. participation in class activities, discussions, and extracurricular events) [47, 48]; (ii) Meaningful engagement between students and their peers, and with faculty members (e.g. collaborative learning, discussions) [49,50] (iii) time and effort devoted to learning (e.g. studying, attending classes, completing assignments, and actively participating) [51, 52]; (iv) Another perspective considers student engagement as the expenditure of both physical and psychological energy put into academic pursuits [53].

The study also seeks to examine the relationship between academics' digital readiness, student engagement and behavioral intentions. Behavioral intention is a decisive factor in determining the actual adoption and usage of technology. Within the scope of this study, behavioral intention encompasses the extent to which academics express their intention to continue to use eLearning platforms [54]. Moreover, the study will assess academics' readiness to teach online, the preparedness of faculty members in the context of digital transformation as well as the institutional framework supporting OTL. Examining the factors of digital readiness will provide insights into the multifaceted nature of readiness for OTL in higher education settings. Based on extensive literature review and existing digital readiness instruments, this study discusses four areas of digital readiness: self-efficacy, institutional support, digital competence, and digital perceived usefulness.

3. Methodology

3.1 Sample and Data Collection

This study employed a quantitative research method to investigate academics' attitudes toward digital readiness for online teaching and learning through an online survey questionnaire. A total of 400 comprising of both full-time and part-time academics in a public university were invited to take part in the online survey. The academics received an invitation via e-mail with a link to the online survey. The participation in the survey was voluntarily and anonymous. The convenient sampling technique was used for collection of the data. Data was collected over two months and the final sample consisted of 165 academics.

3.2 Measurement

In this study digital readiness for the online teaching and learning was measured using four factors, namely digital acceptance, institutional support, digital competence and digital perceived usefulness. Six items assessed digital acceptance, capturing academics' attitudes fostering acceptance of OTL [55]. Eight items captured the academics' perceptions of the institutional support for OTL [56, 57]. For digital competence, nine items reflected academics' perception of competence in using technology for OTL [58]. Three items were used to measure the academics' attitudes toward digital perceived usefulness [58]. Student engagement was measured using seven items [59], indicating academics' perceptions of their student's engagement with the OTL environment. Behavioral intention was measured using 3 items [60] indicating academics' intention to use technology in their future teaching practice. The 5-point Likert scale (1 = strongly disagree to 5 = strongly agree) was used to operationalize the six constructs which form part of the conceptual model. The academic characteristics study such as gender, age, academic disciplines and devised used for OTL were also captured in this study.

3.3 Data Analysis

The data were analyzed through SPSS using descriptive and inferential statistics. Exploratory factor analysis as a data reduction technique was employed to obtain the dimensions of the model. From the academic perspectives, the findings of this study will uncover the disparities that exist at the University level and will help to formulate strategies for capacity building within the educational framework.

4. Findings

4.1 Summary of the Demographic Profiles

Table 1 shows the summary of the participants' demographic profiles. Among the participants, 67.3% were men (n = 111) and 32.7% were women (n = 54), while 18,8% were full-time and 81.2% were part-time academics. The majority of the participants were in the age group of 36-45 years old, and in the business, management and finance teaching discipline (45.5%). The study also showed that 84.2% of the participants used laptops, followed by 9.1% used tablet, 4.2% used personal computer, while 2.4% used smartphone for digital teaching.

Table 1. Summary of Demographic Profiles

Demographic	Characteristics	Frequency	%
Gender	Male	111	67.3
	Female	54	32.7
Age	25-35	34	20.6
	36-45	56	33.9
	46-55	44	26.7
	55 and above	31	18.8
Academic	Full-Time	31	18.8
	Part-Time	134	81.2
Teaching Discipline	Business, Management and Finance	75	45.5
	Sustainable Development and Tourism	58	35.2
	Innovative Technologies and Engineering	18	10.9
	Health Sciences	14	8.5
Device Used	Personal Computer	7	4.2
	Laptop	139	84.2
	Tablet	15	9.1
	Smartphone	4	2.4

4.2 Academics Perceptions of Digital Transformation Readiness

The finding of this empirical research drives some ideas about the academics' perceptions of their capabilities regarding the use of technology in the teaching process. Exploratory factor analysis (EFA) was used to evaluate convergent validity and discriminant validity of measurement scales. The index at KMO and Barlett's test has statistical significance (Sig. 0.000 < 0.01), showing that the observed analysis is appropriate for factor analysis. The extraction method used was principal component analysis with the rotation method Varimax normalization with Kaiser. Extractions have been considered for values greater than 0.50 and an eigen value greater than or equal to 1 were used (Hair et al., 1995). The factor analysis shows that the variables of the model can be grouped into four factors that together manage to explain 60.85% of the overall variability of the model (Table 2). Descriptive statistics for all measures were calculated. Mean (M), standard deviation (SD), and Cronbach's alpha (α) of the digital transformation readiness are reported in Table 2. Alpha values > .70 were considered as acceptable (Nunnally, 1978). The descriptive statistics (means and SD) by item within the four subscales, including digital acceptance, institutional digital support, digital competences, and digital perceived usefulness were moderated rated high by the participants (Table 2). These findings suggest that the respondents feel confident in their perceived ability to effectively use digital tools and technologies in their teaching practices and perceive themselves as competent in their digital skills and capabilities necessary for navigating digital transformation in teaching.

Table 2. Descriptive Results for Digital Transformation Readiness

Statement for Digital Readiness	Factor Loading	Percentage of variance	Cronbach's alpha	Mean	SD	t-value
Digital Acceptance		**41.290**	**.915**	**3.60**	**.91**	**8.38**
Digital Technologies have improved my online class management.	.718			3.44	1.04	5.47
Digital Technologies have enriched my online teaching and research activities.	.782			3.59	1.11	6.84
Digital Technologies have supported my teaching and student learning.	.709			3.81	1.11	9.33
Digital Technologies have contributed to my interactions with students.	.653			3.21	1.20	2.21
Digital Technologies have enabled me to share learning materials with my student	.607			4.02	1.08	12.06
Digital assessment tools have aided me to monitor my student progress.	.751			3.50	0.98	6.60
Institutional Digital Support		11.120	.824	3.76	.66	14.85
The university provides access to digital channels for communication with students and peers.	.801			3.22	1.00	2.89
The university provides data protection mechanism.	.863			3.32	1.03	3.93
The university ensures that students and resource persons use digital technologies safely and responsibly.	.778			3.41	1.07	4.97
The university needs to provide cutting-edge digital infrastructures and services.	.861			3.98	1.00	12.54
The university needs to create fast, reliable and secure networks that are able to protect data and guarantee the security of interconnected devices and their users.	.868			4.17	0.96	15.65
The university needs to develop digital lifelong learning programs.	.657			4.21	0.85	18.39
The university needs to promote digital change as a continuous process.	.613			4.19	0.88	17.51
The university provides support for training opportunities on digital technologies.	.620			3.60	1.09	7.09
Digital Competences		**4.758**	**.916**	**3.75**	**.78**	**12.21**
I use digital technologies to actively develop my teaching skills.	.699			3.82	1.06	10.00
I use digital technologies to work together with colleagues, both inside and outside of my educational organization.	.747			3.85	1.08	10.13
I am able to use digital platforms (Zoom, Microsoft teams, Google meet, Moodle, etc.) for teaching.	.722			4.33	0.84	20.24
I can use digital technologies to design, plan and deliver lectures and assessment.	.818			4.19	0.88	17.51
Digital technologies are conductive to improving my teaching competence.	.625			3.76	1.04	9.42
I implement project-based learning as online instructional methods related to student-centered, competency-based learning and transformative learning.	.612			3.47	1.05	5.71
I implement online debate as online instructional methods related to student-centered, competency-based learning and transformative learning.	.795			3.33	1.07	3.92
I implement online problem-based learning as online instructional methods related to student-centered, competency-based learning and transformative learning.	.843			3.40	1.01	5.00
I implement online presentation as online instructional methods related to student-centered, competency-based learning and transformative learning.	.717			3.58	1.05	7.08
Digital Perceived Usefulness		**3.677**	**.941**	**3.78**	**.98**	**10.25**
Digital technologies help to improve my teaching activities.	.621			3.87	1.03	10.87
Digital technologies help change the way my students learn.	.670			3.73	1.08	8.75
Digital technologies are helpful to my teaching evaluation and reflection.	.659			3.73	0.99	9.53
Note: $p < 0.000$; KMO-MSA = 0.890; Bartlett's test of sphericity = 4156.42						

4.3 Demographic Profile and Academics' Perceptions of Digital Transformation Readiness

A series of independent sample t-tests were performed to assess if perceptions of the digital acceptance, institutional digital support, digital competences, digital perceived usefulness, student engagement and intention to use technology are different from the level of gender and academic status. The results showed that there is a significant difference between only digital acceptance, digital competences, and intention to use technology and gender. The t-test results in Table 3 shows that male respondents had a higher perception on digital acceptance, digital competences, and intention to use technology. The analysis of respondents through t-test thus revealed significant associations only between gender and digital acceptance ($p = .005$, $t = 7.652$), digital competences ($p = .005$, $t = 8.241$), and intention to use technology ($p = .05$, $t = 3.955$) at the .01 and 0.05 levels, respectively. The findings between the male and female academics were roughly the same for these factors.

Table 3. Results of Independent Sample t-Test by Gender and Academic Status

	Digital Acceptance Mean (SD)	Institutional Digital Support Mean (SD	Digital Competences Mean (SD	Digital Perceived Usefulness Mean (SD	Student Engagement Mean (SD	Intention to Use Technology Mean (SD
Gender						
Male	3.64 (.806)	3.78 (.600)	3.78 (.663)	3.75 (.915)	3.36 (.915)	3.84 (.918)
Female	3.49 (1.10)	3.74 (.772)	3.70 (.990)	3.84 (1.12)	3.39 (.995)	3.83 (1.16)
Academic Status						
Full-Time	3.73 (.945)	3.67 (.466)	3.91 (.832)	3.79 (.832)	3.46 (.811)	3.90 (.835)
Part-time	3.57 (.905)	3.78 (.670)	3.72 (.815)	3.78 (1.01)	3.35 (.968)	3.82 (1.03)

The results further showed that there is a significant difference between 2 factors of digital transformation readiness and academic status (Table 3). It is observed that full-time academics exhibited a significant lower agreement on the perceptions of institutional digital support ($M= 3.67$, $p = .000$, $t = 4.59$), but it had a higher agreement on digital competency ($M= 3.91$, $p = .000$, $t = 3.164$). However, the results of this study also found no significant difference among digital acceptance, digital perceived usefulness, student engagement and intention to use technology between full-time and part-time academics.

4.4 Results of one-way ANOVA

A one-way ANOVA test (Table 4) was used to determine the existence of any significant differences which may exist among the different demographic variables and respondents' perceptions of the factors of digital transformation readiness and attitudes toward student engagement and intention to use technology based on age and academic discipline.

Table 4. Demographic Differences on Digital Transformation Readiness, Student Engagement, and Intention to Use Technology

Analysis of Variance F-Value and Level of Significance						
Factors	**Digital Acceptance**	**Institutional Digital Support**	**Digital Competences**	**Digital Perceived Usefulness**	**Student Engagement**	**Intention to Use Technology**
Age	.765	.458	.664	.734	1.607	.590
Academic Discipline	.915	4.193	1.165	1.788	1.211	.948

Notes: Demographic variables are as follows: Age: 25-35, 36-44, 46-55, 55 and above; Academic Discipline: Business, management and Finance, Sustainable Development and Tourism, Innovative Technologies and Engineering, and Health Sciences

No statistically significant differences were discovered for age of respondents and academic discipline on any of the subscales of perceptions of digital transformation readiness, student engagement and intention to use technology.

4.5 Influence of Digital Transformation Readiness on Student Engagement and Intention to Use Technology

The aim of this study is to identify the key digital transformation readiness that affect student engagement and intention to use technology at the university. Multiple regression analyses were used to determine the factors predicting student engagement and intention to use technology at the university. Table 5 shows the results of regression analyses in which the four factors of digital transformation readiness were used as independent variables and student engagement measure as dependent variable. The four factors of digital transformation readiness together explained 66.9% of the variance in the evaluation of intention to use digital technology, which was significant as indicated by the F-value. The significant values of all four factors were less than the significant level of 0.05. The results indicated that the regression model was statistically significant and that all the four factors of digital transformation readiness positively and significantly influence student engagement and it is observed that digital perceived usefulness has the highest influence on student engagement.

Table 5 further shows the results of regression analyses in which the four factors of digital transformation readiness were used as independent variables and intention to use digital technology measure as dependent variable. The four factors of digital transformation readiness together explained 63.5% of the variance in the evaluation of student engagement, which was significant as indicated by the F-value. The findings revealed that only three factors, digital acceptance, digital competence and digital perceived usefulness influenced intention to use technology, and the highest influence was observed for digital perceived usefulness.

Finally, the influence of the five independent variables, namely digital acceptance, institutional digital support, digital competences, digital perceived usefulness and student engagement on the dependent variable intention to use digital technology were examined. The four factors of digital transformation readiness and student engagement together explained 67.4% of the variance in the evaluation of intention to use digital technology, which was significant as indicated by the F-value. The findings showed that only digital acceptance and digital competence influenced the intention to use digital technology. Another study has reported that experience with online teaching resulted in a positive change in the attitudes of academics toward it [61].

Table 5. Results of Regression Analyses

Influence of Digital Transformation Readiness on Student Engagement		
Independent variables	Standardized Coefficients Beta	t-value
Digital Acceptance	.172	2.019**
Institutional Digital Support	.171	2.473**
Digital Competence	.211	2.518**
Digital Perceived Usefulness	.336	3.377*
R^2 = .635; *p < .01; **p < .05; ***p < .1		
F = 67.760, p < 0.000		
Influence of Digital Transformation Readiness on Intention to Use Digital Technology		
Independent variables	Standardized Coefficients Beta	t-value
Digital Acceptance	.168	2.071**
Institutional Digital Support	.089	1.348
Digital Competence	.279	3.494*
Digital Perceived Usefulness	.365	3.859*
R^2 = .669; *p < .01; **p < .05; ***p < .1		
F = 78.832, p < 0.000		
Influence of Digital Transformation Readiness and Student Engagement on Intention to Use Digital Technology		
Independent variables	Standardized Coefficients Beta	t-value
Digital Acceptance	.147	1.807***
Institutional Digital Support	.069	1.028
Digital Competence	.254	3.136**
Digital Perceived Usefulness	.326	3.338

Student Engagement	.117	1.543
R^2 = .674; *p < .01; **p < .1		
F = 64.101, p < 0.000		

5. Conclusion

This study aimed to understand the extent to which academics embraced the culture of digital transformation and examined the factors of digital transformation impacting on student engagement and their intention to use digital technology for online teaching and learning. The findings of the demographics influenced revealed that male and female academics had roughly similar perceptions for digital transformation readiness, that is, for digital acceptance, digital competences, and intention to use technology. However, full-time and part-time academics considered digital transformation readiness differently and thus showed a difference in their readiness of institutional digital support and digital competence. The results of descriptive statistics further confirmed that the majority of the respondents are ready to embrace the digital transformation for teaching and learning. Further, with online teaching and learning gradually being adopted around the world, this study identified the factors influencing the student engagement and intention to use digital technology at the university. To engage students with the online learning environment, academics should provide guidance to students on how to find suitable e-resources and use e-libraries. It is important to help students have a more positive attitude toward digital learning environment and enhance their learning intentions. Embracing a digital teaching and learning environment provides an opportunity that will motivate both academics and students to become more interactive and engaged to make teaching and learning easier and more flexible.

However, this research has some limitations. The principal limitation of this study is that it targeted only one public university in Mauritius. The second limitation is associated with the sample as it targeted academic staff only and the sample size was relatively small. It would be useful to investigate the current methodology and topic of this study to analyze and compare academic staff and students' perceptions of both public and private universities to generalize the results within the Mauritian higher institution environment. While this is a relatively small study, it offers useful information about the academics' perceptions toward digital transformation when making a transition to online teaching.

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Green Human Resource Management Practices in Society 5.0: A Critical Analysis of Opportunities and Challenges

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Abstract

This paper explores the practices of Green Human Resource Management (GHRM) in Society 5.0 and critically analyses the opportunities and challenges organisations face in their endeavours to practice GHRM. The study exposes the influence of Society 5.0 on GHRM practices. We employed a critical literature review to explore GHRM practices in Society 5.0. The paper reviewed 44 journal articles on GHRM practices and Society 5.0. Findings confirm that data, information and knowledge link GHRM practices with society 5.0. Green human resource management (GHRM) practices are central to organisational competitiveness and sustainability. It integrates human resource management functions with environment management issues. However, Society 5.0 is a human-centric society that cartels environmental issues and social aspects to ensure a comfortable social life. It influences the nature and means of GHRM practices applied in organisations. Thus, GHRM practices in recruitment and selection, training and development, rewards management, performance management and employee relations are connected directly with Society 5.0 through AI, IoT, BDA and DT. Our analysis shows that Opportunities for GHRM practices in Society 5.0 include integrating GHRM practices with the environment, facilitating human-centric solutions, developing strategic and sustainable development and keeping an organisational database. However, practices of GHRM in Society 5.0 are associated with several challenges, including cyber security issues, inadequate personnel and scarcity of resources. Society 5.0 distracts human resource management functions, which results in uncertain GHRM practices. The paper thus recommends precise and apt GHRM practices which utilize available opportunities and minimize challenges in Society 5.0.

Keywords: GHRM practices, Society 5.0, Challenges, Opportunities

1. Introduction

Information and communication technology has made notable progress and growth in the past two decades, particularly the introduction and development of cell phones and the internet [10, 41]. Rapid development has made society progress in different stages from Society 1.0 to Society 5.0 [34]. These phases include society 1.0 (hunting and gathering society), society 2.0 (agrarian society), society 3.0 (industrial society), society 4.0 (information society) and Society 5.0 (super smart society) [27-29, 34].

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Society 5.0 was introduced as a social transformation and development for organisations and society [25, 27]. Through innovation, Society 5.0 incorporates human-centric, environmental and social concerns to capitalize on the efficient and effective use of artificial intelligence (AI), digital twins (DT), Big data analytics (BD), and the Internet of Things (IoT) [31, 40, 43].It integrates virtual with physical space to influence the environment and increases environmental concerns [42]. In so doing it considers digitalization and green society as a twin concept that combines society, environment and economy to influence and promote sustainable development [7, 43]. Society 5.0 was introduced to solve social issues from new perspectives and cultivate a value of everyone at any time and place in a safe environment according to nature [28]. Organisations are adopting super intelligence such as automated air conditions, attendance bio registers, video conferencing, smart cars and car parking which influence the natural environment [41]. Simultaneously, the advanced technologies like IoT and AI used in Society 5.0 standardize energy usage and reduce the wastage of resources.

On the other hand, optimal use of organisational human resources in line with environmental management is termed as "green human resource management" (GHRM). It involves innovation that transforms the organisation from traditional human resource management practices into green human resource management practices [23, 35].Governments and International agencies have raised concerns about incorporating Society 5.0 and environmental management to ensure a positive impact on the natural environment. These include the expansion of sustainable development goals (SDGs) into Agenda 2030 sustainable development goals [6, 27]. This increased pressure on organisations to integrate organisational activities with environmental activities. While green human resource management (GHRM) practices work towards integrating organisational activities influenced by Society 5.0 with environment management, Society 5.0 facilitates digital social innovation (DSI) for organisational transformation [30].Through Society 5.0, organisations have introduced various projects and programs including electronic advertisement on environmental issues, minimum use of paperwork and the use of human resource management information system (HRMIS). Under such circumstances, it becomes important to support organisational transformation to enable the effective use of GHRM practices [7]. Despite the increased research on Society 5.0, there is still unknown information on the practices of GHRM in Society 5.0.

This paper thus intends to answer the following questions:

- What are Society 5.0 and GHRM practices?
- What is the link between green human resource management (GHRM) practices and Society 5.0? and
- What are the opportunities and challenges of green human resource management practices in Society 5.0?

2. Methodology

This paper is based on a literature search whereby secondary sources of data were collected by using critical literature review approach [38]. The study analyzed journal articles mostly from internet research databases. These included Springer, MDPI, Emerald Insight, Wiley online library, Taylor and Francis online, Sage Publication and Elsevier. Relevant keywords were used to facilitate and maximize the retrieval of

information to construct the critical review. Keywords used included green human resource management practices, green HRM practices, GHRM, Society 5.0, IT and super smart society. The study set time limit for searching journal articles in order to capture the evolution of Society 5.0 and also GHRM practices within identified time frame. Journal articles used in this paper included those published from the year 2013 to 2024.The Inclusion criteria mostly considered the relevancy and quality of the journal. Some few journal articles were excluded after reading the titles and keywords. Others were excluded after reading abstracts while others were excluded after the article was read. In total, 44 journal articles were used in the study. The study adopted Shah et al [38] three processes: writing a critical literature paper, critical reading and note-taking, writing a summary of the reviewed literature, organizing the literature review and making a critical analysis. In making a proper critical literature review, we adopted three phases of conducting critical analysis. These are the identification and selection of titles, finding usable literature material from known datasets and reviewing the literature.

Table 1: Critical Literature Review Process

S/No	Particular	Details
1	Type of literature	Critical literature review
2	Period	2013-2024
3	Keywords	*green human resource management practices, green HRM practices, GHRM, Society 5.0, IT and super smart society*
4	Publishing data base	Springer, MDPI, Emerald Insight, Wiley online library, Taylor and Francis online, Sage Publication and Elsevier
5	Type of article	Journal articles
6	Criteria	Relevant and high quality journal article

3. Literature Review

3.1 The Concept of Society 5.0

Society 5.0 was developed in Japan in 2016 in the 5th Science and Technology Basic Plan [14]. It is built on society 4.0, a highly advanced information society called a human-centered society or super smart society [12, 14]. It was introduced to ensure business, society and environmental sustainability by finding social solutions that create a comfortable life [41]. It is called a data-driven society whereby theories of traditional artificial intelligence are improved [32]. It works on data, information and knowledge to merge cyberspace with the physical space system [12, 31]. Society 5.0 is a human-centered society that equalizes an advanced economy by seeking solutions to social problems [42]. Moreover, it involves an innovation approach that comprises and inspires social and economic development and societal growth [34, 42].Society 5.0 is also known to influence the knowledge of information for solving social, economic and environmental problems. Through Artificial Intelligence (AI), digital twins (DT), Big data analytics (BDA) and Internet of Things (IoT), social, cultural and eco-

nomic activities are simplified [25, 29]. Generally, Society 5.0 is the connection of a data-driven society centered on solving social problems by using advanced technology through innovation. For example, AI supports GHRM practices by integrating human resource management functions with environmental management issues [18, 22]. Through online recruitment and selection, applicants can be screened, interviewed and selected. This method reduces hard or physical equipment like paper, big rooms and physical congestion, thus it is in line with sound environmental management. Moreover, Society 5.0 facilitates IoT tasks that require human intelligence, like knowledge, management and solving problems to be performed in a much easier manner [25]. Moreover, IoT enables weather conditions to be detected, processing machines monitored and controlled, and attendance or employee performance monitored and evaluated appropriately [8].

Simultaneously, through Digital Twins, companies can make better decision and improve employees' performance by predicting the future demand of human resource. Employees can also work anywhere through teleworking. Society 5.0 also enables Big data which stores, processes and retrieves employees' data at any time to anywhere [22]. It reduces the use of papers, files and cabinets in keeping employee data to avoid loss of information when needed. In this regard, such processes set employee objectives that facilitate environmental management and perform assessment and evaluation [16].

3.2 The Concept of Green HRM Practices

Green human resource management (GHRM) practices are organisational activities that integrate environmental management agenda with internal and decision-making activities to reduce environmental problems [13, 35]. GHRM practices entail managing employees with environmental aspects, from new staff entry to exiting the organisation [19, 36]. This concept includes all activities done by human resource management such as recruitment, training and development, performance management and rewards management [1, 5, 26]. Organisations reduce paper use by introducing online recruitment, electronic performance management and e-payment. GHRM practices are the "systematic and planned arrangement of conventional human resource management practices with the organisation's sustainability goals" [4, 45]. This means transforming traditional human resource management into modern management that integrates human resource management functions and policies with environmental management policies and practices [1, 11, 33]. GHRM practices are also known to consist of human resource management activities and functions which reduce environmental problems and ensure environmental sustainability and performance [1, 37]. Such basic HR practices are performed electronically in the era of Society 5.0.

Green recruitment and selection (GRS) entails generating a pool of potential applicants and identifying the best fit from them who can demonstrate and match with organisational green and sustainable goals [15, 26]. In a super smart society, the process can be carried out effectively and simplified as the organisation can capture the best talent from different places, thus creating a recruitment database [17]. Through online recruitment and selection, the organisation can aim at reducing not only environmental pollution as the process can be online but it can be achieved using less amount of time [45].The Internet of Things (IoT) and Big Data (BD) set the recruitment and selection criteria to encourage candidates with the desire and capabilities to

fit the organisational green goals [24]. Using Society 5.0 in recruitment and selection enables the organisation to reduce the cost of paper, travelling, advertisements and interviews [21]. In line with the same, creating an online recruitment portal in which anyone with qualifications can apply, is likely to simplify the selection process online, making it more transparent causing no undue injustices to applicants [9]. Thus, through Society 5.0, the organisation acquires the quantity and quality of staff it needs at a reasonable cost. Amrutha and Geetha [3] argued that recruiting and selecting the right people, with green attitude, for the right job at the right time is vital for environmental sustainability.

Green training and development (GTD) is the process of on-the-job learning which enables an employee to get new skills and knowledge to continue nurturing organisational goals for a sustainable environment [9]. Training and development increase employees' capability to contribute to environmental performance [20]. GTD also stimulates individual and voluntary work behaviour and employee green knowledge that increases employees' involvement in environmental management [15, 21]. These practices influence creativity and innovation in environmental management and increase organisational competitiveness [20]. GTD enhances capability and stimulates green behaviour, involving employees in environmental management. Through GTD, employees also learn about environmental management policies and standards mandatory to ensure a sustainable ecosystem within and outside the organisation [24, 26]. In line with the above, Amrutha and Geetha [3] also argue that GTD adds aptitude to employees, enabling them to obtain green knowledge for an ecosystem which, in turn, ensures organisational competitiveness as well as sustainability.

Green rewards and compensation management (GRCM) refers to the process of motivating employees with regard to energy skills efforts they contribute to ensure the achievement of the organisational goals [36]. GRCM influences the voluntary involvement of employees in organisational activities that support environmental performance and sustainability [3]. In so doing, GRCM encourages and increases employees' effectiveness, efficiency, and innovation. Rewarding and compensating employees with satisfactory and equitable payment improves organisational competitiveness and environmental sustainability. Thus, GRCM involves both intrinsic and extrinsic motivation which can be monetary or non-monetary rewards [15]. These are crucial for organisational development and creating psychological voluntary and individual green behaviour in employees [15]. GRCM is also about arrangement and encouragement that build confidence in involvement in environmental management after acquiring pro-environmental behaviour [21]. As argued by Mashala [24], Green rewards and compensation management is regarded as reinforcement and incentives in cultivating employees' green attitudes and behaviour.

Green Performance Management (GPM) is the practice of planning, setting, evaluating and assessing employees' performance and contributions to environmental management [9]. GPM involves green auditing, evaluation and environmental policy assessment in which an employee contributes to the organisation's achievement [24]. GPM is also the process where employers and employees set agreeable objectives including environmental objectives to be attained within a specific time frame [9]. It involves assessing and evaluating objectives set against the resources available to employees to ensure that suitable measures are taken as regards employees for either promotion or demotion. In so doing, GPM assesses individual contributions and

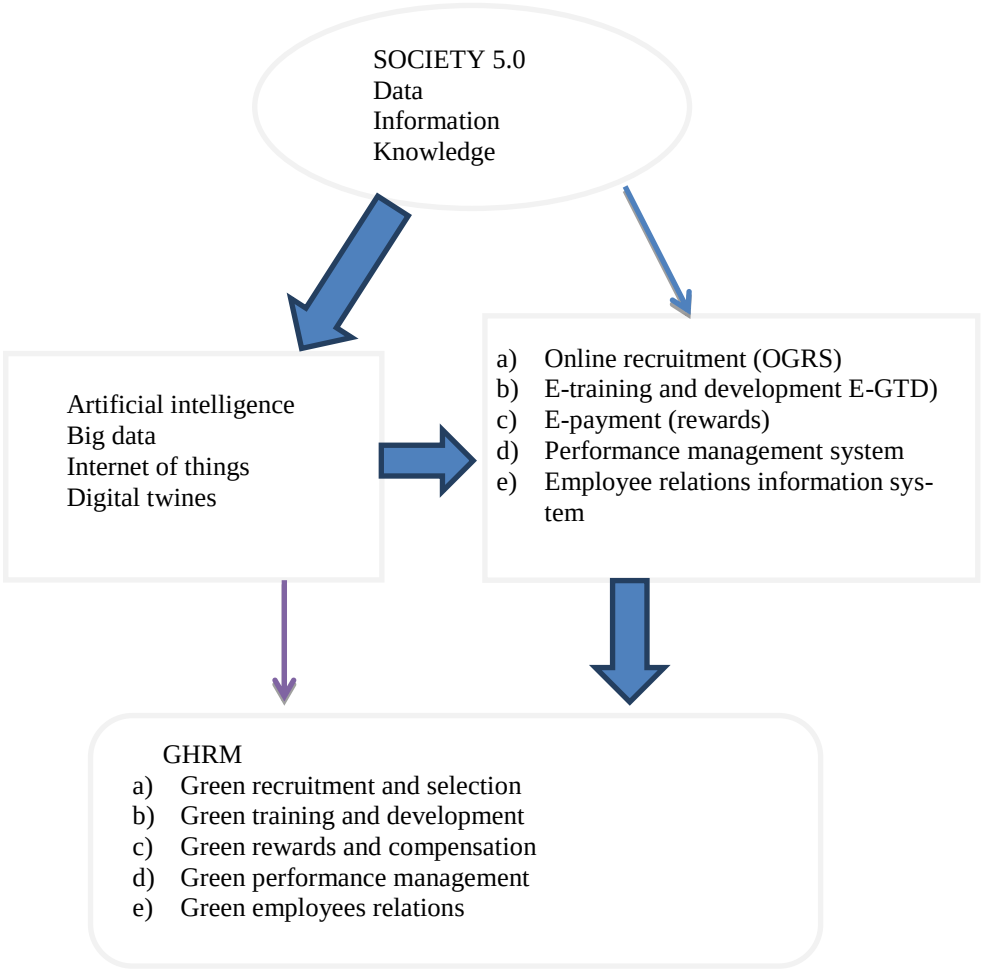
communicates to the employee the performance outcomes on the environment against the target set with an employer on environmental objectives [15]. Mashala[24] explains that GPM includes setting organisational objectives relating to environmental management that allows employees to contribute to environmental management. It thus ensures commitment, effectiveness, innovation and creativity through employee feedback from top management or supervisors [3].

Green employee relations and involvement (GERI) is the relationship between the employer, employees and the government [9, 44]. GERI allows employees to be involved in different employment related issues in the organisation. GERI refers to participation in decision-making, organisational activities and the exchange of information between employers and employees [44], which is a crucial component of environmental management [21]. In building employees' trust and psychological green behaviour, GERI allows employees to be involved in policy-making and programs for environmental management [15, 37, 44]. GERI thus influences employee confidence and willingness to participate in environmental issues to ensure organisational competitiveness and environmental performance [3, 9]. The harmonious relationship between employer and employees in the organisation and the government (state) cement the culture of sustainability and environmental management [24].

3.3 Linking GHRM Practices and Society 5.0

As portrayed above, existing research indicates that GHRM practices are rightly connected with Society 5.0 in various ways. While Society 5.0 is based on data, information and knowledge, GHRM is closely related to online and electronic human resource management (E-HRM) functions [43, 45]. Society 5.0 allows integration of system with network in Artificial intelligence, Big data, Internet of things and Digital twines with E-HRM functions. E-HRM functions like online recruitment and selection (ORS), E-training and development (E-TD), E-payment (rewards), Performance management system and Employee relations information system contribute to environmental management. E-HRM practices stimulates minimum use of paper, reduce physical gathering and effective use of resources. It encourage and motivate individual and voluntary participation through online training, online performance appraisal and employee relation system. Society 5.0 cultivates pro-environmental behavior (PEB), green psychological climate, individual voluntary green work behaviour and green employee knowledge as IoT, AI simplify work performance [11]. Society 5.0 enhances efficiency and effectiveness of GHRM practices. Online recruitment and selection, performance management can be automated done [41].

Figure 2: The Link between GHRM and Society 5.0



Source: Research, 2024

3.4 Opportunities of GHRM practices in Society 5.0

GHRM practices are linked with Society 5.0 through the application technologies and necessary behaviour regarding the organisation's basic HR practices. Society 5.0 not only stimulates but also brings about the practical application of green human resource functions [29]. For example, organisational communication is now accessible and straightforward; storing and accessing employees' data has been simplified to ensure quick access to information. Society 5.0 also clarifies and simplifies the practice of GHRM, which allows employees to acquire green knowledge through electronic training and online advertisement [22]. Thus, Society 5.0 has the potential to cultivate pro-environmental and green psychological behaviour, which is agreed upon and rewarded through performance management systems and electronic rewards in GHRM. In this regard, Society 5.0 ensures effective practices of GHRM through web

and internet technology [40]. Through Society 5.0, organisational systems are made easier by applying AI, Big data, IoT or DT) [12]. GHRM practices are linked and connected with Society 5.0 so that environmental issues can be traced or learned using information technology like AI, BD and IoT. Thus, employees' green behaviour is enabled to enhance sustainability and competitiveness [5].

Organisations reduce the use of paper and other environmental pollutants by conducting online recruitment and selection, which allows and simplifies advertisements in which candidates can apply online; selection is conducted online or via video conference [22]. Online performance management includes setting environmental objectives among employee-given objectives. Automatic evaluation allows recommendations for appropriate measures concerning environmental management [40]. Society 5.0 enables the organisation to set online payments for all employees in different places. Automatic salary calculations and increments build employee green behaviour [2]. GHRM practices are linked with Society 5.0 because, through web and internet technology, employees get access to different information regarding environmental management and receive online training and notification on environmental knowledge. Society 5.0 has simplified the spread of information to employees on green knowledge and allows participation in environmental management. Society 5.0 is applied in all green HRM practices like recruitment and selection, training and development, performance management, rewards and compensation management as well as job design and evaluation. It allows smooth and effective integration of HRM practices with environmental management.

3.5 Challenges of GHRM practices in Society 5.0

The introduction and development of Society 5.0 aims to solve social problems and bring about life comfort for everyone. However, some challenges are evident in the adoption of such practices. These include: cyber security issues, confidentiality, privacy and readily available collection, transmission and distribution of data [43]. When conducting business and executing data, organisations should ensure that the same is not being used otherwise. Organisations' and individual information must be secured, which may otherwise increase environmental problems [39]. For example, if there is information about environmental preservation or eco-friendly motivation, the information may exacerbate the situation and pose a threat instead of reducing problems. The challenge of acceptability of Society 5.0 is also being felt globally. Some employees are unwilling to supply information online thinking about their privacy and security of the systems. Issues of data security in the application of IoT, for example, the use of nodes and networks, do not guarantee trustworthiness, hence creating deficiencies in the system [26]. Issues of internet connectivity, data authenticity and bargaining power inhibit many people worldwide. Society 5.0 creates and allows distant work, reducing effectiveness, engagement and scope of socialization in GHRM practices [43]. The organisation can make work arrangements that enable everyone to work anywhere through teleworking and video conferences. This reduces motivation, socialization, and employee relations. Using the internet and flexible work allows employees to participate in environmental issues including environmental management campaigns, activities and training. Some employees may shun participation. The integration of Society 5.0 with GHRM practices demands highly qualified personnel with both human resource and environmental knowledge.

4. Conclusion

Society 5.0, also known as the super smart society and GHRM practices, is considered to be the integration of human resource functions with environmental management. Practices of GHRM in Society 5.0 are critical to organisational competitiveness and sustainability. Green recruitment and selection, training, rewards, employee relations, and performance management transform the employees from traditional to green behaviour. Applying AI, IoT, BD, and digital twins in the organisation steers positive or negative GHRM practices. Positive impacts include cultivating pro-environmental behaviour, employee green behaviour, and individual and voluntary green work behaviour, which are, in fact, the prerequisites for GHRM. Adoption of human-centric society through Society 5.0 stimulates efficiency and effective use of technology and information in recruitment, training, performance management, and rewards. Integrating GHRM practices in Society 5.0 is essential for an organisation to ensure environmental performance.

However, the challenges should not be overlooked for more effective and cautious adoption of GHRM in Society 5.0 since the security of employee data and well-being is primordial for a sustainable organisation.

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A Framework for Industry 4.0-Related Organizational Transformation

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Abstract. The global landscape is undergoing a profound shift from the industrial age to the cyber-physical era, where interconnected products and services wield significant influence over both society at large and individual organizations. As a distinctive form of strategic change, digital transformation reshapes the way value is created within organizations, emphasizing the need for continuous renewal of organizational capabilities to drive this evolution successfully. In an attempt to guide an organizational transformation roadmap, this study adopted a design science research (DSR) approach to develop a comprehensive framework to assist organizations in navigating Industry 4.0 transformation. The iterative DSR cycles of awareness, suggestion, development, evaluation, and conclusion were systematically applied, utilizing diverse data collection methods. The resultant framework encompasses 15 key organizational capabilities, 4 supporting capabilities and 9 monitoring mechanisms, intricately linked to the dynamic capabilities of sensing, seizing, transforming, and supporting. Moreover, these capabilities are strategically prioritized to guide organizations through the complexities of transformation, with embedded monitoring mechanisms facilitating real-time assessment. The operationalization of the framework through visualization and application guidelines furnishes organizations with a lucid roadmap for comprehending and prioritizing their Industry 4.0 transformation journey.

Keywords: Industry 4.0, digital transformation, organizational capabilities, organizational digital transformation.

1 Introduction

Digital transformation is a strategic response to digital technology trends and became a strategic imperative rather than just a technology implementation [1]. Facing the challenge of digital transformation and addressing the need to remain competitive, organizations must articulate and execute strategies that consider digital transformation implications and enhanced operational performance [2]. According to Li [3], digital transformation is described as the modern struggle to survive the threat of digital disruption so as to successfully manage the transition between the current and future organization. Furthermore, the recalibration of the organization's transformation path must be informed by frequently evaluating progress [4, 5].

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Notwithstanding the substantial expected impact of Industry 4.0 and digital transformation, organizations struggle with overseeing the complexity of the organization [6-8]. Hence, organizations must be empowered to drive digital transformation and create business value by attending to priorities that will add the most value to the organization [9, 10]. Because of digital transformation strategies, strategic management processes and organizational capabilities considered within the prospects and challenges brought about by Industry 4.0 [11], the purpose of this study is to establish the components and application of a framework that will guide organizations in Industry 4.0 transformation.

Therefore, this paper investigates the following research question: "*What are the components of a framework that will guide organizations regarding Industry 4.0 transformation?*". By understanding the components of a framework that will guide organizations regarding Industry 4.0 transformation, organizations will be able to better understand and execute Industry 4.0 related transformation,

The rest of this paper is structured as follows: Section 2 contains an overview of the literature and the research approach in Section 3. In section 4 we present a discussion on the findings, while section 5 details the contribution of the study. Section 6 concludes the paper.

2 Background

The world is changing significantly as the era of the cyber-physical world, where connected products and services have broad consequences for society in general and organizations specifically, replaces the industrial era [12-14]. Worldwide, the rapid development of digital technology fundamentally shifted organizational strategies and operations [3].

2.1 Strategic organizational perspectives of industry 4.0

The technological and conceptual understanding of Industry 4.0 has evolved significantly since its initial German conception in 2011 [15]. The evolution of digital technologies, interconnectedness, smart systems, and cyber-physical systems, as well as the application of these technologies in digital transformation strategies in organizations, enriched the concept and understanding of Industry 4.0 [12-14]. Digital transformation in organizations is characterized by increased automation and data-driven decision making, resulting in a digital convergence between organizational business models, internal operations, and business processes [16-18]. Furthermore, organizations are better positioned to meet customer demands based on intelligent cyber-physical systems that are enabled to make autonomous decisions [15, 19]. Hence, Nosalska, Piątek [16:849] define Industry 4.0 as "a concept of organizational and technological changes along with value chains integration and new business models development that are driven by customer needs and mass customization requirements and enabled by innovative technologies, connectivity and information technology integration".

The successful deployment of these organizational and technological changes hinges on factors that vary from executive management involvement, team capabilities and clearly defined strategies, rather than just on the technology itself [6]. Organizations,

therefore, must be able to drive digital value chains, thus creating more agile and market-focused competencies [9, 10].

2.2 Organizational and technological transformation strategies

To cope with the organizational and technological transformation related to Industry 4.0, organizations need to fully appreciate the complex characteristics of Industry 4.0 [20, 21]. Therefore, digital transformation strategies have to be conceptualized in terms of technological changes, as well as in terms of organizational dimensions, such as strategy, business process, people, internal support functions and culture [6] to realize sustainable competitive advantage [9, 22]. Hence, digital transformation strategies are driven by organizational value creation, with an emphasis on automation and digitalization [9, 23].

From a business perspective, the benefits of enabling technologies relate to operational benefits (e.g. production development and production quality), managerial benefits (e.g. continuous improvement and risk management), strategic benefits (e.g. product innovation and sustainability) and organizational benefits (e.g. improved working conditions and worker assistance) [17, 24, 25]. Considering digital transformation strategies in the context of opportunities and challenges presented by Industry 4.0, organizations have to rethink their business models, operating models, products, services and processes [11]. As digital transformation represents a specific type of strategic change, where business value is created through digital assets, organizations need to consider their retort to digital technology trends as a strategic response [11, 26].

2.3 Industry 4.0 capabilities, digital transformation capabilities and dynamic capabilities

Based on the definition of Industry 4.0 (refer to section 2.2) and the Industry 4.0-related organizational capabilities required, its particular interrelationship to organizational digital transformation must be contextualized [27]. Industry 4.0 drives transformation in organizations, and the practical implementation impacts both the digital and non-digital aspects of the organization [28]. Hence, as Industry 4.0 holds the potential to improve technology- and capabilities-based innovation, the utility of its applications is captured in a digital transformation strategy [27]. Bhattacharya and Momaya [27] capture the drivers of such an Industry 4.0-inclusive digital transformation strategy by identifying global industry trends, new technologies and innovation, and competitiveness as leading drivers. Bhattacharya and Momaya [27] identified existing delivery processes and networks, organization culture and existing standard operating procedures as drivers that may offer resistance to change. Peerally, Santiago [29] identified Industry 4.0 technological capabilities to be incorporated into organizational transformation: retrofitting and readiness capabilities (legacy operation integration and technology acquisition), system integration capabilities (physical-digital technology integration and prototyping), enhanced horizontal and vertical digitalization capabilities (critical digitalization needs identification and implementation across the organization) and smart-intelligent capabilities (self-optimization and scaling).

Incorporating Industry 4.0 capabilities is transversal as it cuts across the entire organization in a dynamic and non-linear digital transformation process [29]. Understanding the context of Industry 4.0 and digital transformation capabilities enables organizations to address specific strategy dilemmas during digital transformation implementation [27, 28].

Dynamic capabilities, as defined by Teece [30], involve a organization's ability to sense changes in its environment, seize new opportunities, and transform its resources and processes accordingly. Sensing refers to the capacity to detect market shifts and technological advancements, seizing involves the rapid deployment of resources to capitalize on identified opportunities and finally, transforming involves the adaptation and reconfiguration of internal capabilities to sustain competitive advantage over time.

2.4 Industry 4.0 and digital transformation capabilities' monitoring mechanisms

As organizational capabilities aid competitive advantage, differentiation, flexibility, innovation, a knowledgeable workforce and responsiveness to changes in the dynamic business environment, they have a direct impact on an organization's viability [31, 32]. Scholars widely recognize the practice in organizations to measure organizational performance based on strategy implementation and execution objectives [5, 33, 34]. However, a lack of appropriate resources and capabilities may hinder efficacy in an organization [5]. To remain competitive, deal with transformative change and navigate digital complexity, organizations must constantly renew their organizational capabilities [35, 36]. Adaku, Ankrah and Ndekugri [36:6] studied capability measurement constructs and identified "resources, ability, integration, governance and management system, task, and superior performance, as components". Adaku, Ankrah and Ndekugri [36] posit that these tangible and intangible components must be integrated within a management and governance system to ensure superior organizational performance. Therefore, organizational capability measurement instruments are tools that aim to assess the level and quality of an organization's ability to perform certain tasks or functions [37-39].

3 Methodology

This study aimed to design a framework that will guide organizations regarding Industry 4.0 transformation and applied a DSR to design the utility [40]. DSR applies a process whereby a new artefact is created [40]. When the knowledge required for designing the artefact does not exist, a research process must be followed to gain the required knowledge and build the artefact. This artefact can then be evaluated, and feedback can be provided to improve the artefact, resulting in an iterative and incremental process [40].

The study concluded 4 design steps, each with its unique data collection and data analysis methods to create the framework for Industry 4.0 transformation summarized in Table 1. For each design step, the data collection and data analysis methods are specified.

Table 1. Design Science Research steps to develop framework.

Design Step	Design step purpose	Data collection method	Data Analysis method
1	Defined Industry 4.0 strategic organizational perspective	Systematic Literature Review	Thematic analysis and axial coding
2	Identified key organizational capabilities impacted by Industry 4.0	Semi-structured interviews	Thematic analysis
3	Identified key organizational capabilities related to Industry 4.0	Semi-structured interviews	Thematic analysis and thematic network graphs
4	Prioritized key Industry 4.0 organizational capabilities towards organizational transformation	Expert interviews	Thematic analysis

The data collection, data analysis and framework design are discussed in the next section for each design cycle. For each step, the detailed data tables are available on a link to the data as the following sections only contains the summary of findings.

4 Findings and discussion

4.1 Step 1: Defined Industry 4.0 strategic organizational perspective

Data was collected by conducting a systematic literature review. A rigorous, standalone and systematic methodological approach must be used for an structured literature review to deliver optimal results [41]. The process defined by Boland, Cherry and Dickson [42] was chosen for this study and consisted of three steps: planning the review, conducting the review and reporting the review. The keywords chosen were “4IR” and “strategic alignment” and “organisation”; “fourth industrial revolution” and “strategic alignment” and “organisation”; and “I4.0” and “strategic alignment” and organisation”. After applying inclusion and exclusion criteria, as well as quality assurance, 37 papers were analyzed in detail identifying 10 Industry 4.0 related organizational capability themes through descriptive codes [38] and through open coding to identify emerging main themes [39]. The 10 themes identified related to a strategic organizational perspective of Industry 4.0 included external drivers, Industry 4.0 relevant strategy, business value, workforce, technology, customer value, process, data, organizational change, and product. The first version of the framework that will guide organizations regarding Industry 4.0 transformation is shown in Table 2. The detailed data may be access here: https://www.researchgate.net/publication/379189640_41_-Step_1_Defined_Industry_40_strategic_organizational_perspective.

Table 2. Framework version 1 for Industry 4.0-related organizational transformation.

Strategic alignment domain	**Industry 4.0-related aspect**
Service level	Human-centric organisational change
	Workforce education, productivity and wellbeing
	Customer experience differentiation

Competitive potential	Process optimisation and value chain digitalisation
	Product customisation and portfolio innovation
Technology potential	Data and Big Data management towards data-driven decision making
	Technology-centric convergence and digital ecosystem potential
Strategy execution	Market and industry external drivers and disruption
	Industry 4.0-relevant strategy and organisational structural alignment
	Business value improvement through digital business model innovation

4.2 Step 2: Identified key organizational capabilities impacted by Industry 4.0

Data for this step was collected via semi-structured interviews. Based on the outcome of Step 1 (Section 4.1), a semi-structured interview guide was designed. This guide consisted of two sections. Firstly, respondent demographic information (e.g. organizational level and tenure). Secondly, questions regarding key Industry 4.0 organizational capabilities. Purposive sampling was used to select the nine respondents, guided by the respondent's experience and knowledge relating to the research study [43]. The semi-structured interview data was analyzed using content analysis. According to Krippendorff [44], content analysis is a technique for analyzing audio, visual or textual content to identify underlying themes, patterns and meanings. It systematically organizes and interprets this content to draw inferences and insights regarding specific research objectives. In addition, for version 2 of the framework, the organizational capabilities were mapped to the dynamic capabilities defined by Teece [45] shown in Table 3. Color coding was applied to improve readability and associations related to the organizational dynamic capability columns. The 10 Industry 4.0 related organizational capability themes identified in step 1 were confirmed by the interviewees and were enriched with 4 additional themes identified in the semi-structured interviews. The detailed data may be access here: https://www.researchgate.net/publication/379189728_41_-Step_2_Identified_key_organizational_capabilities_impacted_by_Industry_40.

Table 3. Framework version 2 for Industry 4.0-related organizational transformation.

	Organisational dynamic capabilities			
Strategic alignment domain	**Sensing**	**Seizing**	**Transforming**	**Supporting**
Service level			Customer experience differentiation	Human-centric organisational change
			Organisational culture and continuous learning	Workforce education, productivity and wellbeing
Competitive potential		Product customisation and portfolio innovation	Process optimisation and value chain digitalisation	Talent management, continuous learning and expertise domain development
			Efficient product delivery and product personalisation	
Technology potential	Data and Big Data management towards data-driven decision making	Technology-centric convergence and digital ecosystem potential		
		Competitive solutions development and services provider relationship management		

Strategy execution	Market and industry external drivers and disruption	Business value improvement through digital business model innovation	Industry 4.0-relevant strategy and organisational structural alignment	Communications and information sharing tools and personalisation
	Strategic leadership accountability, initiatives and objectives	Informed and data-driven decision making	Virtual and differentiated new and/or optimised business models	

4.3 Step 3: Identified key organizational capabilities related to Industry 4.0

The objective of this step was to understand the key organizational capabilities related to Industry 4.0 and how organizations can monitor these capabilities. Data for this step was collected using a semi-structured interview process. A semi-structured interview guide was designed based the findings from steps 1 and 2 i.e., the questions were informed based on the strategic alignment domains and the Industry 4.0-relevant organizational capabilities. Eighteen purposive sampled respondents of all industry types and organizational levels were identified to get a broader perspective across organizations. The interviews were transcribed and analyzed using thematic analysis, specifically thematic networks. Thematic networks are web-like schematic diagrams that show the relationship between basic, organized and global themes [43, 46]. The process of creating thematic networks from the interview data starts with identifying basic themes in the data. Basic themes are identified by assigning initial labels and then grouping them according to organizing themes based on relatable data. Lastly, organizing themes are grouped together into global themes. In this step, the 14 Industry 4.0 related dynamic organizational capabilities were enriched to 18 Industry 4.0 key organizational capabilities and nine capability monitoring mechanisms shown in Table 4. The detailed data may be access here: https://www.researchgate.net/publication/379216067_Section_43_-Step_3_Identified_key_organizational_capabilities_related_to_Industry_40_Industry_Sector_of_Participants_Number_Participant_level_in_the_organisation.

Table 4. Framework version 3 for Industry 4.0-related organizational transformation.

Organisational dynamic capabilities			
Sensing	**Seizing**	**Transforming**	**Supporting**
Data and Big Data management towards data-driven decision making	Product customisation and portfolio innovation	Customer experience differentiation	Human-centric organisational change
Market and industry external drivers and disruption	Technology-centric convergence and digital ecosystem potential	Organisational culture and continuous learning	Workforce education, productivity and wellbeing
Strategic leadership accountability, initiatives and objectives	Competitive solutions development and services provider relationship management	Process optimisation and value chain digitalisation	Talent management, continuous learning and expertise domain development
	Business value improvement through digital business model innovation	Efficient product delivery and product personalisation	Communications and information-sharing tools and personalisation
	Informed and data-driven decision-making	Industry 4.0-relevant strategy and organisational structural alignment	
		Virtual and differentiated new and/or optimised business models	
Monitoring mechanisms			

Monitor competitive advantage and new developments	Monitor efficacy in product delivery, improve product versatility and digitally driven production	Continually monitoring the organisation's business value through repeat business	Monitor technology architectures, interconnectedness and business solutions for customers and workforce
Monitor global drivers, regulation and compliance		Monitor customer experience optimisation and improve the customer touchpoint processes	Monitor and improve workforce digital literacy
Monitor analysis and derivation of data-driven insight towards organisational innovation and new ways of working		Monitor optimised processes through process governance and automation	

4.4 Step 4: Prioritized key Industry 4.0 organizational capabilities towards organizational transformation

In the final DSR step, version 3 of the framework for Industry 4.0-related organizational transformation was evaluated by four industry experts by means of a semi-structured interview. The semi-structured interview guide was designed to understand the framework's utility from an organizational perspective and the summarized feedback from the respondents that impacted the final visualization of the framework.

The initial response to the framework from all interviewees was positive. All interviewees confirmed that the framework comprehensively covered industry 4.0-related organizational capabilities. In addition, the proposed capability prioritization of the frameworks received very positive comments, and interviewees confirmed that the framework would support the creation of an organizational roadmap for digital transformation. The interviewees also confirmed that the framework was visually appealing, and easy to understand and to follow. Positive feedback was also shared om the monitoring mechanisms as interviewees reflected that the framework generally provided concepts only, without the addition of monitoring these concepts. Two interviewees noted the importance of realizing that not all organizations are mature enough to handle every capability. Therefore, the organizations capabilities must first be determined before being guided on a digital transformation journey. Interviewee 4 remarked that the organizational transformation process is not always so formal or straightforward. Sometimes, an external event can force transformation onto an organization without proper time or investment into sensing and seizing. Additionally, interviewees agreed that Industry 4.0 is mainly connected to differentiation and the ability of an organization to set itself apart from other similar organizations.

Interviewees 2 and 4 agreed that data is key in Industry 4.0 organizational transformation, supporting that the sensing capability data and Big Data management towards data-driven decision-making must be a high priority. Additionally, interviewee 2 emphasized that organizations can only be transformed through their organizational capabilities. All interviewees noted that prioritizing and monitoring the organizational capabilities part of the framework will cause them to choose this framework more readily over other similar frameworks.

After applying the feedback from the expert interview, the resultant framework encompassed 15 key organizational capabilities, 4 supporting capabilities and 9

monitoring mechanisms (refer section 5 and visualization in Fig.1. The detailed data may be access here: https://www.researchgate.net/publication/379218013_Section_44_-Step_4_Prioritized_key_Industry_40_organizational_capabilities_towards_organizational_transformation.

5 Framework for Industry 4.0 organizational transformation

The framework depicted in Figure 1 that will guide organizational transformation regarding Industry 4.0 was developed through 4 design science research steps. This framework consists of 18 organizational capabilities distributed over four dynamic capabilities: sensing, seizing, transforming, and supporting. The supporting dynamic capability operates across sensing, seizing, and transforming. Additionally, the 18 organizational capabilities are prioritized, and monitoring mechanisms are provided to aid organizations to monitor each capability as the organization transforms.

When organizations start a transformation journey, they must consider the importance of managing organizational outcomes and consequences related to Industry 4.0, specifically considering both the organizational and technological dimensions. Organizational capabilities, such as strategy, business processes, workforce skills, culture, and business models, play a crucial role in this transformation. However, organizations face financial constraints, resistance to change, lack of planning and skills, standardization and technology integration issues, and the absence of feasibility studies and business cases. Therefore, for efficient and effective organizational transformation, organizational capabilities can be prioritized to address challenges and ensure optimal resource allocation aligned with business value creation.

To guide organizations to effective and efficient industry 4.0-related transformation, the organizational capabilities were included as priorities. Hence, under the sensing dynamic capability, all three organizational capabilities, data and Big Data, external drivers, and strategic leadership, were highly prioritized. For the seizing dynamic capability, the product organizational capability was assigned high priority and business value was assigned a medium to high priority. The organizational capabilities of software services and solutions, and decision making were assigned a medium priority. Finally, the technology organizational capability was assigned a low priority.

For the transforming dynamic capability, the product efficacy organizational capability was assigned a high priority, and the process was assigned a medium to high priority. The organizational capability Industry 4.0-relevant strategy was assigned a medium priority. Finally, the organizational capabilities customer value, organization and business model were assigned a low priority. The high-priority organizational capability for supporting dynamic capability is skills and expertise. The workforce organizational capability was assigned a medium priority, and the organizational capabilities organizational change and communication were assigned a low priority.

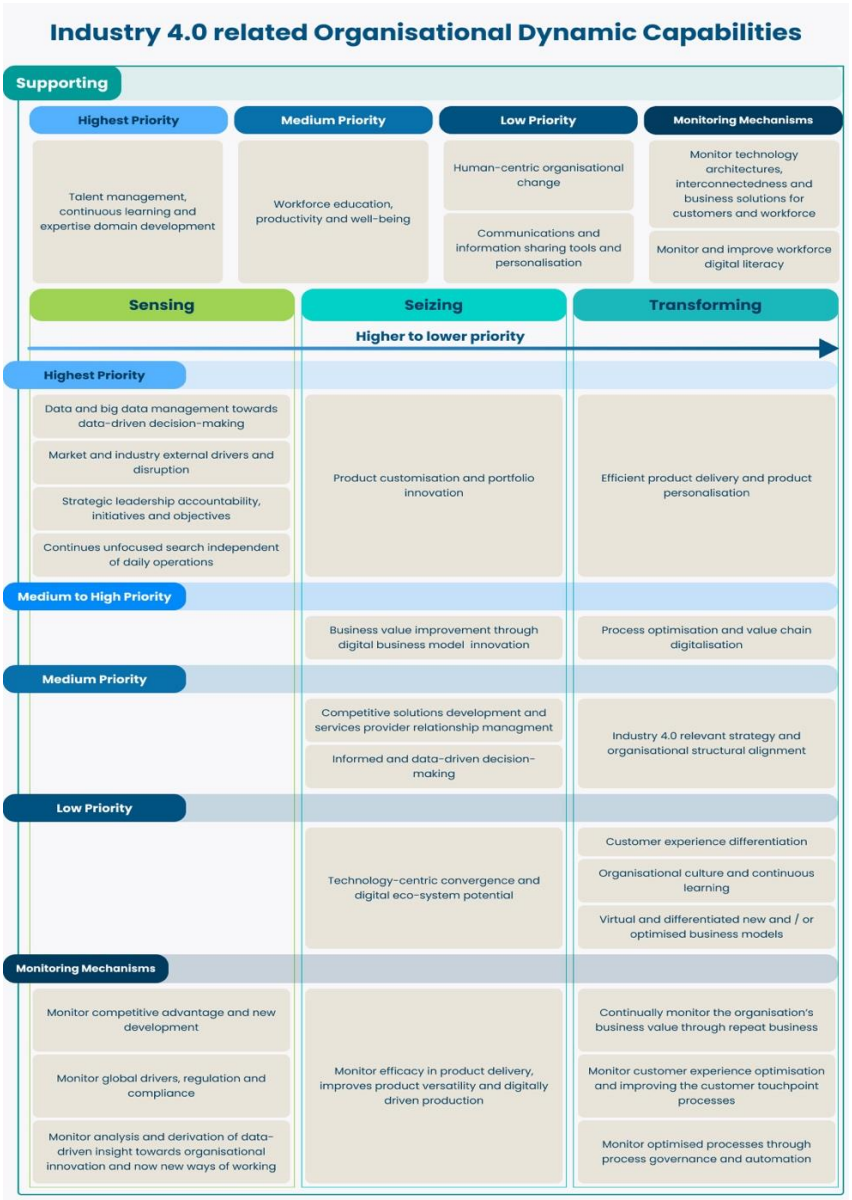

Fig. 1. Framework for Industry 4.0 -related organizational transformation.

6 Conclusion

The aim of this paper was to establish the components and application of a framework that will guide organizations in Industry 4.0 transformation. The framework for Industry 4.0 -related organizational transformation was designed through four steps of design

science research and the resultant framework encompasses 15 key organizational capabilities, 4 supporting capabilities and 9 monitoring mechanisms, intricately linked to the dynamic capabilities of sensing, seizing, transforming, and supporting. Due to the impact of digital transformation strategies and the challenges and opportunities presented by Industry 4.0, the developed framework will assist organizations in navigating their transformation journey within this context.

The study specifically targeted organizations from various industries for interviews and questionnaires; however, it is important to acknowledge that the participants did not encompass representatives from all industry sectors. Consequently, the study may not fully capture the spectrum of organizations possessing capabilities for digital transformation. Additionally, it is noteworthy that the research focused exclusively on organizations in South Africa, limiting the geographical scope of the study to a specific region. This geographical constraint implies that the findings may be influenced by the unique contextual factors and business environments prevalent in South Africa, potentially impacting the generalizability of the results to a global context. Therefore, the study's outcomes should be interpreted within the context of its industry and geographical limitations.

Regarding recommended future research, an option is to apply the framework in real-world scenarios as a use case study. This use case could add valuable insight into the framework's utility in an organizational context and further enrich the framework.

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Game-Based Learning – an Innovative Approach to Pedagogy

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Abstract. The field of education is always evolving, driven by continuous technological developments and profound insights into pedagogy. Game-based learning (GBL) is a prominent breakthrough that is prevalent in this field. The integration of gaming elements with educational content is rapidly gaining popularity, resulting in enhanced learning experiences and outcomes. Game-based learning, particularly in the context of higher education, offers an appealing deviation from traditional instructional methods. It fosters an educational setting that is engaging, immersive, and captivating, diverging from the monotonous routine. This approach aligns not just with the technological proficiency and preferences of modern learners but also with emerging theories in the fields of educational psychology and cognitive science. These theories support the idea that cognitive and psychological outcomes can be significantly enhanced through the use of dynamic learning techniques. The objective of this conceptual paper is to critically examine the existing literature on the psychological and cognitive advantages of incorporating game-based learning in the context of higher education. This paper aims to thoroughly examine the complexities of this learning approach, encompassing its definition, various varieties, and implementation from existing literature. Furthermore, its objective is to provide explanations for its advantageous effects on the mind and psychology, reveal the inherent difficulties and limitations it possesses, and offer suggestions for its successful application. Moreover, this will establish a foundation for subsequent investigations, promoting a more comprehensive understanding of the significant impact that game-based learning has on tertiary education.

Keywords: Game-Based Learning, Learning Approach, Pedagogy, Higher Education

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1 Introduction

Technological advancements and the growing prevalence of online learning have brought about substantial changes in the realm of education in recent times. To improve learning outcomes and increase student engagement in light of this new reality, academic institutions are continually investigating novel pedagogical approaches. Game-based learning, an emerging approach, leverages digital games as instructional technological instruments. Game-based learning is an instructional approach that incorporates fundamental principles and elements of gaming into the learning and teaching process. The purpose of this paper is to investigate the potential advantages of game-based learning within the context of higher education institutions. A qualitative examination of the extant literature on game-based learning in higher education constitutes the methodology of this conceptual paper. This paper offers an analysis of the importance and consequences of game-based learning, with a particular focus on the efficacy of gamification tactics in stimulating learners and improving the educational experience.

1.1 The Concept of Game-Based Learning

Game-based learning is an educational approach that effectively combines educational content with a dynamic gaming environment, creating an interesting, interactive, and immersive learning environment for students (Justin Marquis 2023; Perrotta et al. 2013; Shah 2017; Wiggins 2016). It is characterized by several essential attributes, namely:

Engagement: Games can captivate students' attention and foster active participation in the educational journey. The interactive nature of these resources serves to maintain students' motivation and foster a high level of engagement in their academic pursuits.

Interactivity: Game-based learning provides a platform for students to make decisions and solve problems, thereby improving their cognitive capacities and problem-solving skills through intentional interactions inside the gaming environment.

Evaluation of Performance and Progress Monitoring: Games offer prompt feedback, functioning as an opportunity for learners to assess their progress and implement essential adjustments. Students can assess their development and progress over a specified duration by utilizing the progress monitoring feature.

Legitimacy and Simulation: Games frequently emulate authentic scenarios, providing students with a secure and regulated setting in which to implement the knowledge and abilities they have gained. The presence of authenticity enhances the practicality of acquired notions within real-world situations.

Adaptability: Game-based learning demonstrates a high degree of flexibility since it is capable of accommodating the unique needs and learning preferences of individ-

ual students. Games can be designed with several levels of difficulty, providing a customized learning experience for students.

Game-based learning encompasses a wide range of categories, each with its distinct educational focus and goals. Game-based learning generally falls into the following prevalent categories (Bakhsh et al. 2022; Irwansyah & Izzati, 2021; Marquis 2023; Liu et al., 2020; Perrotta et al. 2013; Sonsona et al., 2021):

i. Quiz Games: These educational activities assess students' understanding using quizzes, providing prompt feedback and reinforcing comprehension of acquired topics.
ii. Simulation games: Such games serve as a means to replicate real-life circumstances, hence enabling the practical application of theoretical information. Illustrative instances encompass medical simulations and aviation simulators.
iii. Adventure games: These games are characterized by their focus on narratives, which engross players in compelling storylines and challenge them to solve puzzles and surmount obstacles to advance.
iv. Role-Playing Games (RPGs): By allowing students to assume the personas of fictional characters and engage in quests, RPGs foster the development of critical thinking, problem-solving, and collaboration abilities.
v. Strategy Games: Engaging in these games necessitates students to exercise strategic thinking and forethought to influence the course of the game. Instances include games such as civilization-building and chess.

2 Adoption of Game-Based Learning in Higher Education

The prominence of game-based learning in higher education has increased as a result of its capacity to enhance student motivation, engagement, and learning outcomes (Karagiannis & Magkos, 2021; Naim & Razak, 2023; Plass et al., 2020; Reuter et al., 2022; Tavares 2022; Yamani 2021). Game-based learning has been widely adopted by educational institutions and instructors through diverse techniques for application:

Stand-Alone Courses: Certain institutions proffer dedicated courses or modules that predominantly utilize game-based learning as the main instructional methodology. These courses weave game mechanics and elements into the curriculum, offering an immersive and interactive learning journey to students.

Supplemental Learning Instruments: Game-based learning can also serve as an ancillary tool to augment traditional teaching methodologies. Educators may integrate educational games or gamified activities to reinforce key notions, assess knowledge, and extend additional learning opportunities.

Virtual Learning Spaces: Online platforms and virtual learning environments open doors to game-based learning. These platforms provide a plethora of educational

games and simulations that can be accessed remotely, offering flexibility and accessibility to students.

Collaborative Learning: Game-based learning fosters collaboration and teamwork among students. Educators may curate multiplayer games or group-oriented activities that necessitate students to collaborate, thereby fostering communication, problem-solving, and interpersonal skills.

3 Benefits of Game-Based Learning

Game-based learning has become increasingly recognized and embraced as a novel educational approach. The paper examines the multifaceted nature of games as learning environments, drawing on previous research in the field. It emphasizes that to fully comprehend their impact, it is necessary to consider multiple perspectives. By incorporating insights from cognitive, affective, motivational, and sociocultural theories, we explore experiential learning-enhancing design elements. Through the integration of these various perspectives, the educational potential of games can be thoroughly realized.

Undeniably, game-based learning serves as an instrumental tool in fostering a heightened level of motivation and engagement in students. According to the research conducted by Plass et al. (2015), the compelling and engrossing characteristics of game-based learning provide a distinct capacity to stimulate students' curiosity and interest, hence augmenting their motivation to acquire knowledge. When gaming is combined with instructional content, it creates a strong drive for students to actively participate in and persevere through difficult assignments. Enhanced motivation possesses the capacity to produce superior academic achievements and foster a more positive outlook on the process of learning (Reuter et al., 2022). In addition, the immediate feedback and incentives through game-based learning serve as a trigger for maintaining student motivation. The students are provided with prompt feedback on their performance within the game, allowing them to evaluate their progress, advance and adjust accordingly. Moreover, the embedded rewards and recognition in game-based learning, such as the attainment of new levels or the acquisition of virtual badges, bolster students' sense of achievement and provide additional motivation to continue their educational journey.

Conventional learning environments may sometimes lead to anxiety and stress, especially when students are subjected to high-stakes evaluations or competitive scenarios. Contrastingly, game-based learning introduces a more relaxed and supportive atmosphere, thereby reducing anxiety and stress levels. Research by Kapp (2012) suggests that game-based learning fosters a secure environment where students are

free to explore, experiment, and learn from their mistakes without fear of negative repercussions. This flexibility to make mistakes and learn from them encourages a growth mindset and generates a positive emotional state, which is conducive to effective learning.

Game-based learning plays a pivotal role in enhancing students' self-efficacy and self-confidence. As students conquer the in-game challenges, they develop a sense of competence and conviction in their capabilities. This newfound confidence transcends the gaming environment and positively influences their overall academic performance (Connolly et al., 2012). By surmounting in-game hurdles and celebrating their successes, students nurture a stronger sense of self-efficacy, equipping them with the confidence to tackle complex tasks and challenges head-on.

Additionally, game-based learning aids in refining emotional regulation and coping strategies. Within the game environment, students encounter a spectrum of emotions, from frustration to excitement to satisfaction. As they navigate these emotional landscapes, they learn to manage their emotions and effectively handle challenges. The emotional regulation skills and coping mechanisms acquired during game-based learning can be applied to real-life scenarios, assisting students in managing stress and adversity (Naim and Razak, 2023).

Studies have highlighted the capacity of game-based learning to enhance the critical thinking and problem-solving abilities of higher education learners (Hartt et al., 2020; Kapp 2012; Naim & Razak 2023; Nikoletta-Zampeta et al., 2020; Perrotta et al., 2013; Connolly et al., 2012). Games require students to engage in strategic thinking, take decisive action, and solve complex problems. These activities help students develop their analytical skills and ability to make reasoned judgements. In the dynamic world of games, students are faced with a plethora of challenges. To surmount these, they must employ logical reasoning, devise efficient strategies, and navigate through obstacles to reach their goals (All et al., 2021; Sonsona et al., 2021). This stimulating process of critical thinking and problem-solving extends beyond the confines of the game, seeping into real-world contexts and fostering the growth of vital cognitive abilities.

Game-structured learning has been found to have a positive impact on the retention and transfer of knowledge, hence providing an additional cognitive advantage. Games create a platform for frequent practice and application of conceptual knowledge across varying contexts, thereby reinforcing students' comprehension and memory of information (Marquis, 2023). The all-encompassing and immersive nature of games engages multiple senses, which intensify the encoding and consolidation of newly acquired knowledge (Hartt et al., 2020). Also, games often present information in a

visually enticing and memorable fashion, simplifying the process of recollection and application of learned concepts in diverse scenarios (Karagiannis and Magkos 2021; Plass et al., 2020; Tavares 2022).

Game-structured learning can also benefit tertiary education students by enhancing their psychomotor abilities. The development and refinement of psychomotor abilities are facilitated by some games that require physical movement or manipulation of objects. For example, healthcare education leverages simulation games to allow students to practice clinical procedures in a risk-free virtual environment, thereby enhancing their dexterity and coordination (Georgieva-Tsaneva & Serbezova 2020). This aspect of game-based learning is especially advantageous in fields that need practical skills and direct application (Tavares 2022).

In addition to these, game-structured learning has been identified as a catalyst for the development of metacognitive skills, which form the backbone of self-regulated learning. Engaging in gameplay encourages students to introspect their strategies and decisions, thereby nurturing self-awareness and metacognitive consciousness. Through this process, students acquire the ability to set objectives, monitor their learning trajectories, and assess the efficacy of their learning strategies. This heightened metacognitive awareness can be carried over to other learning contexts, emboldening students to take charge of their learning journey and evolve into more autonomous learners.

To encapsulate, game-based learning presents an array of psychological and cognitive advantages for students in higher education. It boosts motivation and engagement, mitigates anxiety and stress, nurtures self-efficacy and confidence, and develops emotional regulation and coping skills. Additionally, it enhances the capacity for critical thinking and problem-solving, promotes the retention and transfer of knowledge, supports the growth of psychomotor skills, and fosters metacognitive capacities These advantages culminate in a more comprehensive and holistic learning experience, encouraging students to mature into active and engaged learners. However, it is crucial to bear in mind that game-structured learning is not devoid of its unique set of challenges and limitations.

4 Challenges and limitations of Game-Based Learning

Game-based learning has been praised for its ability to keep students interested and improve their learning, but it faces many major problems. As more educators investigate the integration of games into formal educational environments, they confront a variety of challenges that affect the feasibility and efficacy of this strategy.

The process of integrating education into the core of gaming encounters several challenges. One of the most significant obstacles lies in the considerable financial investment and enormous time commitment necessary for the development of instructional games of exceptional quality. Developing games that effectively combine educational material with captivating gameplay is a complex and time-consuming task. The successful integration of games with learning objectives and the facilitation of meaningful learning experiences necessitate a cohesive collaboration among instructional designers, game developers, and educational experts.

One further challenge encountered in the context of game-based learning pertains to the task of convincing educators of its efficacy. Challenges may arise due to resistance to change and scepticism surrounding the effectiveness of game-based learning when compared to conventional teaching approaches. Nevertheless, it is imperative to provide empirical evidence that supports the notion that game-based learning has a beneficial influence on student involvement, motivation, and academic achievements.

The widespread adoption of game-based learning may be hindered by the digital divide. Disparities in technology and internet access among students can impede their participation in game-based learning activities. Moreover, the accessibility difficulties are further complicated by the significant variation in the availability of suitable hardware and software platforms among educational institutions.

Quantifying the learning outcomes in game-based learning environments can be a complex process. Traditional assessment methods may not fully encapsulate the diverse range of skills and knowledge acquired through such experiences. Therefore, innovative approaches, such as performance-based assessments and the integration of analytics within games, are necessary to evaluate student progress and achievement accurately.

For effective implementation of game-based learning in tertiary education, evidence-backed game selection and design are key. Games should align with the intended learning objectives and be supported by research on their effectiveness.

Gradual integration of game-based learning into existing curricula, through scaffolding, can facilitate a smooth transition for both students and educators. Ongoing evaluation and iteration are essential for continuous improvement and refinement of game-based learning practices.

5 Implementation Strategies

To effectively incorporate game-based learning into higher education, it is crucial to prioritize the selection and design of games based on empirical research. The selection of games should not only align with the desired learning outcomes but also be supported by empirical evidence demonstrating their effectiveness. The selection process requires a thorough examination of the features, mechanics, and instructional content of each game to verify that they effectively contribute to the desired learning goals. Furthermore, the development of games that effectively combine engagement and instructional impact necessitates a collaborative endeavor between game creators and educators.

Another essential requirement is to ensure that game-based learning activities are in line with the overall learning goals of the course or curriculum. The games need to be smoothly incorporated into the existing educational structure, augmenting and enriching the content and skills being imparted. This alignment breeds coherence and consistency in the learning journey, equipping students to apply the knowledge and skills gleaned from the game to real-world scenarios. Educators have a responsibility to clearly communicate the learning goals to students and openly connect them to game-based activities.

To ensure a smooth transition to game-based learning, it is preferable to use scaffolding tactics and progressive integration. Scaffolding involves handing students the necessary support and guidance to successfully navigate the game-based learning landscape. This support may comprise tutorials, hints, and feedback aimed at enabling students to surmount challenges and hone their skills. Gradual integration implies the step-by-step introduction of game-based learning activities, giving students and educators time to acclimate to the novel approach. This methodology curbs resistance to change and ensures students are well-equipped to welcome game-based learning.

Undertaking regular evaluation and refinement is a crucial part of successful game-based learning implementation. Educators must routinely gauge the effectiveness of the games and learning activities, soliciting student feedback and scrutinizing their performance. This feedback fuels the iterative design process, paving the way for enhancements and fine-tuning based on the learners' unique needs and preferences.

Constant evaluation also empowers educators to swiftly identify and address any potential impediments to learning.

6 Conclusion and Way Forward

Game-based learning (GBL), an innovative pedagogical approach that incorporates interactive games, presents educators with dynamic strategies to captivate and inspire students. Through the integration of gaming elements with educational content, instructors can establish immersive environments that encourage active student engagement in the learning process.

Neuroscience plays a crucial role in understanding the impact of game-based learning on cognitive and psychological processes within the context of higher education. Through the examination of brain activities and processes in the context of game-based learning, it becomes possible to explore the distinct cognitive functions and neural networks that are activated throughout the gaming encounter. Advanced neuroimaging techniques such as functional magnetic resonance imaging (fMRI) and electroencephalography (EEG) have the potential to provide valuable insights into brain activation patterns and neural connectivity during learning experiences.

Exploring the applicability and effectiveness of game-based learning methodologies in higher education can be enlightened through comparative research across a multitude of disciplines. An in-depth analysis of the effects of game-based learning in many academic domains, including the sciences, humanities, and social sciences, can provide a comprehensive comprehension of its possible advantages and disadvantages in multiple contexts. Comparative research can also highlight discipline-specific elements that influence the effectiveness of game-based learning strategies and direct the development of unique methods for every discipline.

While existing research has underscored the immediate benefits of game-based learning, there is an impending need for longitudinal studies to gauge its long-term effects on learning outcomes. Such studies can scrutinize the retention of acquired knowledge and skills over an extended period, and investigate the potential influence of game-based learning on students' future academic performance and professional accomplishments. Longitudinal research can also offer insights into the lasting psychological and cognitive benefits of game-based learning and the degree to which these benefits are applicable in real-world situations.

Qualitative studies centered on students' perceptions and experiences of game-based learning can supplement quantitative measures, offering invaluable insights into the subjective aspects of this learning methodology. Comprehending students' attitudes, motivations, and challenges associated with game-based learning can guide the design and execution of effective learning interventions. Qualitative research can also explore factors that affect students' engagement and satisfaction with game-based learning, as well as their preferences for different game elements and designs.

As a revolutionary approach to higher education, game-based learning, in summary, possesses substantial potential. The psychological and cognitive advantages of this tool, along with its ability to promote engagement and motivation, render it a powerful instrument for augmenting the learning process. Nevertheless, it is essential to thoroughly analyze the difficulties and constraints, along with implementing techniques that are supported by evidence, to effectively exploit its capabilities. Continued research and exploration of game-based learning will undeniably contribute to its further development and integration into educational practices, ultimately shaping the future of higher education.

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Unlocking The Full Potential of Digital Transformation: Exploring The Role of Enterprise Architecture 2.0

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Abstract. The integration of digital transformation is now an essential component of achieving success for contemporary organizations. This transformative process can be leveraged to improve customer experience, streamline internal processes, boost efficiency and productivity, innovate new services and products, and formulate more effective growth strategies. However, organizations struggle with driving the adoption of new tools and processes, addressing change resistance, technology choices, security concerns and inefficient data management. Therefore, the purpose of this paper was to investigate the organizational benefits of applying Enterprise Architecture (EA) 2.0 for digital transformation. It was established that EA 2.0 promotes nine organizational benefits including strategic alignment, efficiency and optimization, decision-making and risk management, customer-centric focus, innovation and competitive advantage, change management and long-term sustainability, collaboration and communication, data management and insights, and vendor and resource management. By understanding these benefits, organizations may optimally exploit the potential value creation of using EA 2.0 for digital transformation

Keywords: Digital transformation, enterprise architecture, organizational benefits, enterprise architecture management, Society 5.0

1 Introduction

Organizations undergo an increasing level of digital transformation as technology advances [1, 2]. From automating business processes to utilizing big data analytics [3], digitalization is essential to competitiveness in today's fast-paced business world [3]. Digital transformation is defined as "a process that aims to improve an entity by triggering significant changes to its properties through combinations of information, computing, communication, and connectivity technologies" [4]. Enterprise Architecture (EA) helps organizations solve real problems faced during the digital transformation process by guiding the search for, and implementing, real solutions [5]. To understand and optimize how organizations operate, they must possess in-depth knowledge of their

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internal environment [6]. Through implementing EA, organizations can obtain the nec-essary knowledge of their internal business processes, procedures, technology and In-formation Technology (IT) architecture levels [7].

Organizations operate within environments classified into two classes: the target and external environments [6]. The external environment encompasses factors that impact organizations, but these factors are beyond the organization's ability to influence [8]. The target environmental factors can influence or initiate change in an organization and can be managed by an organization [8]. The ultimate goal of EA is to continuously align the organization's target (internal) environment with the ever-changing external- environment [9, 10]. Therefore, this study aims to consider: "*What are the organiza-tional benefits of applying Enterprise Architecture 2.0 for digital transformation?*". By identifying the organizational benefits, organizations can understand the potential value creation of applying EA for digital transformation, while ensuring that the focus on a human-centered society stays intact [10].

The rest of the paper is structured as follows: firstly, we provide background on digital transformation and EA in section 2, followed by the methodology to identify the organizational benefits in section 3. In section 4 we provide an overview of the data analysis and findings. The paper closes with the discussion in section 5 and a conclusion in section 6.

2 Background

In the digital transformation era, controlling the architectural landscape for an organization is important. The architectural landscape guides organizations to pinpoint the problems and equips organizations with practical, digitally transformative solutions [11]. This control enables organizations to optimize their resources, ensuring they are allocated at the correct cost and time to drive digital transformation initiatives [7].

Most definitions of EA address its constituent parts, namely "enterprise" and "architecture". The Open Group bases their definition of EA on the ANSI/IEEE Std 1471-2000: "*the fundamental organization of a system, embodied in its components, their relationships to each other and the environment, and the principles governing its design and evolution*" (https://publications.opengroup.org/).

2.1 Society 5.0 and Enterprise Architecture 2.0

Society 5.0 aims to solve societal and economical dilemmas through combining human-centric and cyber-physical opportunities [12]. The aim of Society 5.0 therefore presupposes that transformative processes in the cyber-physical domain, will impact humans, by promoting a ubiquitous computing society and significant changes in the world of work, as well as life in general [12]. Where EA initially focused on IT implementation (EA 1.0), EA 2.0 is about a mindset and culture that focuses on the entire organization [13]. Therefore, EA 2.0 drives transformation for the whole organization, continuously mapping business key performance indicators to organizational architecture in order to enable continuous measurement and continuous improvement [2, 13].

EA frameworks offer numerous advantages by fostering a shared understanding of an enterprise system by; facilitating improved communication among stakeholders, identifying and addressing existing problems within an organizations, restructuring established organizations, redefining operations and processes, managing complex changes, integrating intricate systems, maintaining comprehensive records for future reference and collaboration, monitoring and predicting organizational performance, and overseeing operational control [14]. In essence, they serve as a comprehensive framework for optimizing enterprise functionality and ensuring effective management [2] and consist of a set of generally accepted standards that help to simplify the architecture development process and ensure that all the dimensions and perspectives are considered and are well understood by all stakeholders [14]. Examples of EA frameworks includes; the Zachman Framework for EA, the US Government's Federal Enterprise Architecture Framework (FEAF), The Open Group Architecture Framework (TOGAF), the US Department of Defence Architecture Framework (DoDAF), and the UK Ministry of Defence Architecture Framework (MoDAF) [14, 15].

An EA approach is at the forefront of facilitating, enhancing, and ensuring strategic responsiveness and agility in digital transformation [16]. This approach employs a robust and adaptable composite methodology [17] that spans the entire digital transformation journey – from defining the overarching business strategy to the successful implementation of IT assets [7].

2.2 Digital transformation and Enterprise Architecture

Digital transformation, as enabled by EA, goes beyond the technological realm [2]. It also entails a cultural shift within an organization. Embracing change becomes second nature through effective change management initiatives [18], fostering an environment where employees accept and actively contribute to the digital transformation journey [13]. One of the most compelling aspects of EA is its role in aligning an organization's IT capabilities with its digital transformation strategy [2]. This alignment empowers organizations to gain a competitive edge and sustain that advantage over rivals in the dynamic market driven by digital disruptions [19]. As organizations progress in their digital transformation journey, their EA maturity levels evolve, requiring a shift from traditional functional- and business unit-level architectures towards more comprehensive enterprise-level architecture [19]. This shift in maturity brings increased complexity and intensity, mirroring the multifaceted nature of digital transformation itself [19].

As organizations delve deeper into digital transformation, they may encounter numerous hurdles, including integrating outdated legacy systems that pose barriers to digital transformation [1]. Furthermore, effective governance and security of data sources become paramount as organizations navigate the digital terrain [20]. Additionally, cultural barriers may surface when employees resist changes brought about by new technologies and workflow transformation [21]. Effective EA strategies are important to unlocking substantial benefits in the digital transformation landscape [22]. These benefits extend to streamlined business processes, crucial for staying competitive in the digital age [23]. By ensuring the adoption of a formal EA approach and addressing the

challenges posed by digital transformation head-on, organizations can fully realize the immense potential for positive change and growth [1].

3 Research Approach

The objective of this paper to identify the organizational benefits of applying EA 2.0 for digital transformation initiatives in an organization. In order to achieve the objective, a systematic literature review (SLR) was undertaken to systematically collect, assess, and amalgamate the extensive body of research, scholarly contributions, and practical work documented by researchers, scholars, and practitioners [24]. A SLR must be conducted based on a rigorous and systematic methodological approach [25, 26]. We followed the methodological approach suggested by Boland, Cherry and Dickson [27] consisting of 3 main stages: *planning the review* (research objective definition and review protocol), *conducting the review* (primary study selections and data extraction) and *reporting the review* (report distribution) [25, 28]. The search terms applied were "enterprise architecture" and "digital transformation" and "organizational benefits" using Google Scholar and accommodating the USA and UK English “z” vs. “s” [29]. A result set of 115 papers were identified based on inclusion criteria such as peer-reviewed publications, journal papers, conference proceedings and technical reports. The corpus identified were screened by applying specific criteria such as studies not associated with the research question, anecdotal or opinion-based papers, duplicate papers and non-English studies. After the initial screening, as well as the application of inclusion and exclusion criteria, we concluded a detailed screening of abstracts and analysis of the full-text of the potential papers. A total of 48 papers were selected for an in-depth analysis and were coded and themed. This data analysis approach made it possible to thoroughly summarize and contextualize the results of various investigations, allowing the discovery of recurring themes, patterns, and qualitative insights [30].

4 Data Analysis and Findings

Data was extracted from the final corpus and expressions describing EA and digital transformation in an organizational context were extracted into an MS EXCEL worksheet. Once all the expressions extracted were identified, sub-themes and main themes were identified through two steps: firstly, descriptive codes were used to identify sub-themes [31] and secondly axial coding was used to identify emerging main themes [32]. Axial coding is the process of identifying and consolidating relationships between themes and categories that have been identified during the descriptive coding step [33]. Table 1 shows the emerging main themes, the sub-themes based on the phrases of text extracted, and the references.

Strategic alignment in EA can be likened to a lighthouse, serving as a guiding force for organizations to ensure that their digital transformation initiatives are effectively integrated with and aligned with their broader strategic goals. The importance lies in allocating resources towards technological advancements and strategically aligning these expenditures. Such resource allocation assures the appropriate concentration and

priority of efforts by facilitating the efficient allocation of resources. Moreover, within the contemporary context of the swiftly progressing digital landscape, agility is not merely a desirable quality, but an indispensable requirement. EA promotes agility by effectively integrating technology with organizational objectives and maintaining adaptability.

Table 1. Organizational benefits of applying EA 2.0 for digital transformation in Society 5.0

Main-theme	Sub-Theme	References
Strategic alignment	Strategic goal alignment: EA ensures digital transformation efforts align with the organization's strategic objectives.	[34-36]
	Resource optimization: EA helps allocate resources effectively to support digital transformation initiatives.	[5, 7, 37]
	Agility enhancement: EA fosters agility by aligning technology with business goals and promoting adaptability.	[10, 19, 38]
Efficiency and optimization	Operational efficiency: EA identifies process optimization and automation areas, reducing operational costs.	[7, 18, 39]
	Complexity reduction: EA promotes standardization and simplification, reducing organizational complexity.	[36, 40]
	Cost savings: Through optimization, EA can reduce costs across the organization.	[41, 42]
Decision-making and risk management	Informed decision-making: EA provides a structured framework for informed technology decisions.	[43, 44]
	Risk mitigation: EA identifies and addresses risks associated with digital transformation projects.	[45-47]
	Compliance and Governance: EA helps enforce compliance and governance policies.	[48, 49]
Customer-centric focus	Enhanced customer experience: EA guides the development of customer-centric digital solutions.	[1, 50]
	Data-driven insights: EA supports data integration and management for personalized customer interactions.	[23, 51]
Innovation and competitive advantage	Innovation enablement: EA identifies opportunities for innovation through emerging technologies.	[9, 11, 52]
	Competitive edge: EA enables rapid response to market changes and delivers innovative solutions.	[8, 16, 53]
Change management and long-term sustainability	Change management support: EA provides a roadmap for transitioning to new technologies and processes.	[17, 54, 55]
	Long-term sustainability: EA ensures digital transformation initiatives are adaptable to evolving needs.	[56, 57]
Collaboration and communication	Enhanced collaboration: EA fosters collaboration among business units and departments.	[58, 59]
	Communication framework: EA serves as a common language for effective communication.	[8, 22]

Data management and insights	Data analytics: EA supports data integration and analysis for informed strategies.	[20, 60]
	Security and compliance: EA assist in securing and managing data in compliance with regulations.	[61, 62]
Vendor and resource management	Vendor management: EA provides vendor selection, negotiation, and alignment insights.	[3, 63]
	Resource efficiency: EA ensures the efficient allocation of resources to support digital transformation.	[4, 6, 21]

Operational inefficiencies can frequently deplete resources and hinder efforts towards change, emphasizing the importance of efficiency and optimization. The utilization of EA reveals these inefficiencies, presenting opportunities for enhancing and automating processes. The outcome frequently entails a noteworthy decrease in operational expenditures. Furthermore, EA mitigates organizational complexity by promoting uniformity and discouraging redundancy. This simplification process subsequently results in concrete cost reductions across diverse company divisions.

The significance of *decision-making and risk management* in digital transformation cannot be overstated. EA provides a comprehensive and systematic perspective, allowing stakeholders to make informed and rational choices. However, selecting appropriate choices is not solely limited to decision-making but also encompasses comprehending and effectively managing the potential hazards. EA is crucial in proactively identifying and mitigating these hazards. In a contemporary context where the importance of adherence to rules and governance policies cannot be underestimated, EA takes proactive measures to guarantee that technology decisions align with these requirements.

In the contemporary era of digitalization, the consumer has a paramount position of authority and influence. EA plays a crucial role in helping organizations shift their focus from being solely technology-centric to becoming *customer-centric*. EA prioritizes facilitating customer-centric digital efforts by implementing solutions that improve the customer experience and enable data integration for more tailored interactions. [50].

The relationship between *innovation and competitive advantage* is such that today's breakthroughs become the minimum requirements for success in the future. EA plays a pivotal role in diligently surveying the landscape for promising opportunities, particularly those arising from emerging technologies. It facilitates the ability of organizations to sustain a competitive advantage by enabling them to promptly adapt to market dynamics through innovative solutions.

The concept of *change management* is closely intertwined with the long-term sustainability of digital transformation. EA offers a strategic framework that enables organizations to effectively navigate and anticipate changes rather than reactively responding to them. This approach guarantees the achievement of long-term sustainability, as digital initiatives possess the capacity to be scaled and adjusted to meet future requirements.

Collaboration and communication are frequently hindered by silos within expansive organizational structures. EA effectively eliminates these boundaries, cultivating a cooperative atmosphere across various organization units and departments and using EA as a shared medium facilitates enhanced and cohesive communication.

Through the generation of significant sets of data, the acquisition of insights holds immense value. The *integration and analysis of data* are strongly advocated by EA, as they empower organizations to extract practical solutions from their data. Security measures must not be neglected or marginalized due to the growing prevalence of data breaches. It must be ensured that data is utilized securely and effectively managed in compliance with regulatory requirements.

Vendor and resource management are integral components of digital transformation, as it is not a solitary endeavour. External partners and vendors frequently assume a pivotal position in this process. EA provides valuable insights into the management of vendors, ensuring that external partnerships align with internal aims. Furthermore, by optimizing resource allocation, EA guarantees the utmost efficiency in utilizing human and technical resources to facilitate digital transformation.

5 Discussion

In order to assess the efficacy of strategic alignment, it is imperative to commence by evaluating the proportion of IT efforts that align with broader organizational objectives. This analysis offers a concise overview of how much technology projects align with the organization's objectives. In addition, the resource usage rate provides valuable insights into the effectiveness of resource allocation in transformation endeavours. Furthermore, agility, an essential principle of strategic alignment, may be effectively measured by evaluating the duration it takes to bring new initiatives to the market. This measure emphasizes the speed at which an organization can adapt and implement modifications.

When focusing on efficiency and optimization, observable outcomes frequently manifest as reductions in operating costs. The effectiveness of EA is evidenced by the direct correlation between its implementation and the reduction in operating expenses, as it pushes process improvements and system overhauls. The metric of system standardization rate, which represents the proportion of processes or systems that have been standardized through the implementation of EA, emerges as a crucial indicator. Furthermore, cost avoidance in EA emphasizes the proactive benefits of preventing needless or duplicative technology expenditures, as it quantifies the savings obtained from such actions.

In the context of decision-making and risk management, the proactive identification and subsequent mitigation of high-risk issues indicate the effectiveness and strength of risk management protocols. In addition to this, the metric of decision-making time has great significance. Organizations can assess the effectiveness and efficiency of their decision-making processes in the context of EA by quantifying the average duration required to reach critical decisions.

These metrics provide a comprehensive and targeted method for evaluating the impact and effectiveness of EA within the context of digital transformation. By analyzing these indicators, organizations can assess the present efficacy of EA and pinpoint areas that require additional refinement and improvement.

6 Conclusion

The aim of this paper was to identify the organizational benefits of applying EA 2.0 for digital transformation initiatives in an organization. A corpus of 48 identified papers were analyzed and organizational benefit themes were identified. The analysis identified 9 organizational benefits (themes) consisting of 21 sub-themes. The advent of the digital era has ushered in ground-breaking innovation, unparalleled expansion, and digitalization asserting organizations to consider their digital transformation strategies. By understanding and considering the organizational benefits of applying EA 2.0 in this context, EA 2.0 signifies a paradigm change in which organizations adopt technology and integrate it into their operations. This study provides further evidence of the importance of structure, strategy, and synchronization in effectively utilizing digital capabilities, with EA 2.0 playing a central role.

It must be acknowledged that the analysis in this study was constrained by a specific choice of keywords ringfencing the corpus extracted for analysis. The organizational benefits list may therefore not comprehensively include all aspects of digital transformation and the impact of EA. In addition, specific organizations, depending on their maturity, may place different importance on certain aspects. However, the limitations also direct further research opportunities. Firstly, the organizational benefits identified may be applied and tested in different organizations to establish the completeness of the identified list and secondly, a scale based on organizational maturity may be developed to further operationalize the findings from this study.

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Corporate Governance Sustainability Regulation: The Impact of Sustainability Competencies on ESG Ratings - An Exploratory Study of European and Japanese Banks

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Abstract. Global lawmakers and standard setters, e.g., the International Sustainability Standards Board (ISSB) as well as many other countries in the world, such as Europe and Japan are continuously shaping their regulatory frameworks in the area sustainability with a strong focus on environmental disclosures and with corporate governance being a rather deprioritized area. This study examines if the number of board directors with sustainability expertise and sustainability leadership has a positive effect on the ESG ratings of EURO STOXX Banks and Japanese TOPIX Banks. Results indicate that sustainability expertise on boards of European and Japanese banks is still rather low, but that sustainability leadership with Japanese banks is relatively high. Nevertheless, ESG ratings of Japanese banks are rather low and much lower than those of their European peers.

Keywords: Sustainability regulation, Corporate Governance, Europe, Japan, Banks.

1 Introduction

The European Commission approved the European Green Deal in 2019 to achieve climate-neutrality for Europe by 2050 [1]. Since then, it adopted a set of regulations, including the EU taxonomy, which entered into force on 12 July 2020 [2]. The current environmental taxonomy has been considered a starting point for a succeeding social and governance taxonomy according to the European Commission [3]. The further development and a approval of a social taxonomy has been put on hold since then due to diverging political views; despite intensive consultations and the findings and appeals of researchers and practitioners emphasizing the necessity of a holistic regulatory framework for sustainability including the social and governance dimension [4,5,6,7]. The development of a governance taxonomy occurs even slower: While the European Commission opened a consultation in late 2020 [1] on the realignment of corporate governance with key aspects of a sustainable economy, a full, separate governance taxonomy report or draft has not been proposed so far but has been included as a rather small part in the report on the social taxonomy [3]. The latter aim to increase corporate governance in firms, amongst others elaborates on “traditional governance factors” [3, p.61], “addressing purely economic issues” [3, p.61], e.g., “ownership and

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shareholders' rights; the composition, development and evaluation of boards; financial reporting and disclosure; qualifications and conflicts of interest of board members; audits; risk management; remuneration; and legal-compliance systems" [3, p.61]. In many countries corporate governance have been taken place [10] since two decades motivated by "a desire for more transparency and accountability […] to increase investor confi-dence" [9].

Japan's corporate governance system has been in the spotlight, with the re-vitalization of its stock market presumably driven by corporate governance reforms [11]. Japan has started to reform its traditional corporate governance system following the bursting of the stock market bubble at the end of the 1980s [8]. The reforms are usually divided into two phases [8]: "First, the period from the early 1990s to the end of 2011, a point in time that in some ways marks the end of the great financial crisis of 2008/9, and second, the period from the time the Abe government took office in 2012" [8, p.93]. The corporate governance code from February 2015 [12] marks the starting point for significant changes in the second phase of reforms. Main goal was to strengthen the weight and influence of independent directors [12]. In 2015, corporate law was changed to allow organizational forms of companies segregating management and supervisory boards [12]. In 2021, for companies listed on the Prime Market of the Tokyo Stock Exchange further regulations were strengthened [8,13]: At least one-third of the direc-tors must be independent outside directors [8], "or the majority if the company has a majority shareholder" [8, p.100]. Also, regulations for other market segments were put in place [8,13]. And companies must explain and disclose the reason and objective of shareholdings in other companies [8,14]. As in many other countries the governance codes are not mandatory [10], but Japan follows the apply or explain approach [14]. In 2022 and 2023 the Tokyo Stock Exchange (TSE) further increased pressure on compa-nies not managing towards increasing "corporate value" [15] and "implementing man-agement that is conscious of cost of capital and stock price" [16]. Further, the TSE requires from non-compliant companies to disclose action plans to increase their price to book ratios to above 1 [16]. This is not the end of regulatory activity, according to CNBC (2024), "the Japanese government and the TSE have plans in the works for in-creasing corporate board independence and female representation" [17].

Global lawmakers and standard setters, e.g., the International Sustainability Standards Board (ISSB) as well as many other countries in the world, such as Europe and Japan are continuously shaping their regulatory frameworks in the area sustainability with a strong focus on environmental disclosures [2,18] with corporate governance being rather a rather deprioritized area of sustainability regulation. Japan's corporate governance reform discussion, still rather focusing on traditional corporate governance factors, might benefit from the initial European discussion on governance factors directly linked to sustainability matters [3] in the EU taxonomy as well as in the Gender Balance Directive [27] and CSDDD [29], in particular in the areas of sustainability competencies in the highest governance body, transparency on sustainability targets and the incentives to achieve these targets as well as criteria on sustainability-linked pay and diversity [3]. This study will focus on sustainability competencies, potentially not only adding to the discussion in Japan, but also to Europe's halt on the discussions [4,5] could be revitalized by a data-driven regulatory impact study.

2 Theoretical Background, Literature Review and Hypotheses

2.1 Theoretical Background and Literature Review

According to the World Economic Forum (2023), 98% of CEOs worldwide consider it as their job to make their businesses more sustainable, but "many are concerned it could hurt their bottom line" [19] but consider it as "more complex and costly […] to sticking to business as usual" [19]. This view is supported by the United Nations Global Compact initiative highlighting that it "is now firmly acknowledged by researchers, investors and executives that corporate sustainability is key to long-term profitability and viability of most, if not all, companies" [20, p.4]. However, some studies find that board directors think too much time is spent on sustainability [30], see little financial impact on the business [32] or feel "ill-equipped" in ESG [31]. Most recently, an analysis from Copenhagen Business School and Competent Boards (2024) found that board's sustainability competency has room for improvement as stated by 84% of public companies in Europe and 76% in the United States respectively [33]. In Japan, ESG competence greenwashing risks up to board level are discussed with regulators and in the press [34]. Also, sustainability expertise on boards is still rather low [1,35]: "Currently, less than one percent (0.8%) of 110,000 directors across 7,226 public companies globally have a professional background in sustainability" [36].

The composition of the highest governance body, e.g., the board, is considered along with other factors (e.g., alignment of interests of the company with directors' duties, focus to the long-term, board remuneration) key to promote sustainable business management [21,22,23]. For similar and additional sustainability related governance factors taken up or being discussed on EU level, e.g., transparency on sustainability targets [24], incentivization [21,22,25,26] as well as sustainability linked board renumeration [21,26] and diversity [43] supportive empirical research could be found.

The resource dependency theory, human capital theory, agency theory and social psychological theory [37,38] provide theoretical background why sustainability competencies on boards help to make companies more sustainable [38]. "These theories aim to explain how external resources of the organization (resource dependency theory [39]), e.g., the board of directors, and their education and experiences (human capital theory [41]), their degree of independence (agency theory [40]) and diversity (social psychological theory [42]) may influence the behavior and performance of the organization" [38, p.130]. So, "the absence of relevant knowledge and expertise inside the board might significantly undermine a board's capacity to identify and discuss sustainability risks and impacts" [1, p.3, 38].

Research on the relationship between board characteristics and the ESG performance of firms most widely uses parameters such as the share of independent directors [43,44,54,55], (gender) diversity [43,44,54,55], (national) diversity [43], board size [43,44,54,55] and the existence of a sustainability committee [43,44,55]. The independence of board members is considered advantageous to promote sustainable business strategies [45,46,47,54,55] by some researchers, while others found contrary results [44,43]. Diversity is a multi-facetted concept encompassing age [55], gender, nationality, race [1] as well as "different backgrounds and experiences – including sustainability

expertise" [38, p.130], positively impacting not only corporate sustainability, but also economic [48] and other extra-financial areas [22,23]. Some studies with a focus on gender representation found a positive impact of female board participation on ESG performance [47,49,54,55] or financial performance [50,47,51], whereas others could not show an impact on financial performance [37,52,53]. Regarding board size, most studies find a positive impact on ESG performance [43,44,55], only one a negative [54]. The impact of sustainability committees on ESG ratings was examined in the Gulf re-gion [49], for Italian banks [55] and for European banks [44] showing a positive influ-ence.

As the banking sector has – through its financial intermediary function [38] – a key function for the transition to a more sustainable economy [44], further studies on the impact of board characteristics on ESG performance were conducted with a focus on the banking sector [37,38]. However, sustainability competencies have only been studied in one exploratory study for European banks in 2021, with no significant results of the impact of sustainability expertise on ESG performance, but of sustainability leadership on Chairperson- or CEO-level [37]. However, since then, regulatory activity in the area of sustainability significantly increased in Europe putting pressure on businesses and potentially boards to increase sustainability expertise. Also the Japanese regulatory activities significantly increased. The impact of board characteristics on ESG ratings has neither been studied for Japan nor for specifically banks in Japan. Studies published so far on Japanese firms showed the impact of board characteristics (e.g., board size, independence, diversity) on environmental performance [56], the influence of top management's personal values [57] or board compensation [58] on ESG performance.

Therefore, this study focuses on the impact of sustainability competencies on boards on the ESG ratings of European and Japanese banks. Results might contribute to the regulatory discussion on fostering sustainability in both Japan and Europe.

2.2 Hypotheses

The given theoretical framework on the resource dependence theory and human capital theory, regulatory requirements and academic research on board characteristics [38,49] provide the theoretical basis why sustainability expertise could influence ESG ratings and a more sustainability oriented way of doing business. Theory and empirical studies [38,49] suggest a positive relationship between sustainability competencies on board level and ESG performance.

To test whether a revitalization in Europe or a consideration in Japan of regulatory discussion and action for sustainability competencies on boards would make sense and impact sustainable business management in firms, the following main hypothesis has been formulated:

Hypothesis 1: The number of board directors with sustainability expertise has a positive effect on the ESG ratings of EURO STOXX Banks 30 and TOPIX 17 BANKS.

The second hypothesis takes account of the fact that previous studies found a positive influence of the CEO or the Chairperson on ESG performance in both Europe and Japan

[37,38,57]. Following Alm and Winberg (2016) who studied the impact of female leadership on firms' financial performance, sustainability leadership will be measured with either the Chairperson or the CEO having a sustainability-oriented profile on the firm's website.
Hypothesis 2: Sustainability leadership has a positive effect on the ESG ratings of EURO STOXX Banks 30 and TOPIX 17 BANKS.

3 Data and Methodology

3.1 Data

In line with recent studies [30,37,54], data on ESG ratings, board of directors' characteristics and further financial data has been collected from Thomson Reuter's DataStream (now acquired by the London Stock Exchange Group) and was complemented for board of directors' characteristics manually from respective corporate websites [37]. Data includes 27 major European banks from the EURO STOXX Banks 30 index and 78 Japanese banks from the TOPIX Banks Index. Following recent studies [37,38,44,47] an 8-year panel dataset (from 2015-2022) has been constructed. The overall sample consists of 4446 director-firm-year observations, after deletion for missing values. Based on recent studies [37,38,54,55], the dependent variable to test the hypotheses represents the ESG performance rating from Thomson Reuters.

The independent variables of primary interest are sustainability expertise on board level (SUSTEXP) and sustainability leadership (SUSTLEAD) and their impact on ESG ratings of European and Japanese banks. Previous research [37,38,44,54] used different control variables, e.g., the share of women on the board of directors (WBOD), the number of foreigners on the board (FORBOD), the age of board members (AGEBOD), the share of independent directors (BODIND), board size (BODS) and the existence of a sustainability committee (SUSTCO). Following previous studies [37,38,54], further control variables are added, which might impact the ESG performance: Bank size (BANKSI), return on equity (ROE), leverage (LEV) and country-specific variables measured by the GDP [37,38,54,59] (see table 1).

Table 1. Measurement of independent / control variables [38, adapted from Waterstraat et al. (2021)]

Independent Variable	Measurement	Exp. Relationship with ESG Rating	Sources
SUSTEXP	Proportion of directors with sustainability expertise divided by the total number of directors on the board	Positive	Ceres (2015)
SUSTLEAD	Dummy variable that is equal to 1 if the bank has a Chairperson or CEO with sustainability profile, 0 otherwise	Positive	Nguyen (2024), Waterstraat et al. (2021), Alm & Winberg (2016)
WBOD	Total number of women on the board of directors divided by the total number of board members	Positive	Miranda et al. (2023), Menicucci et al. (2022), Konstantin & Elena (2022), Arayassi et al. (2020), Rao et al. (2017)

FORBOD	Total number of foreigners on the board of directors divided by the total number of board members	Positive	Konstantin & Elena (2022)
AGEBOD	Average age of board members	None	Menicucci et al. (2022),
BODIND	Percentage of independent board members divided by the total number of board members	Positive / negative	Miranda et al. (2023), Menicucci et al. (2022), Konstantin & Elena (2022), Arayassi et al. (2020), Garas et al. (2017)
BODS	Number of board members	Positive / negative	Miranda et al. (2023), Menicucci et al. (2022), Konstantin & Elena (2022), Birindelli et al. (2018)
SUSTCO	Dummy variable that is equal to 1 if the bank has a sustainability committee, 0 otherwise	Positive	Konstantin & Elena (2022), Birindelli et al. (2018)
BANKSI	Total assets (Euro) of the bank	Positive	Tamini et al (2017), Carter et al. (2010)
ROE	Bank's net income divided by the value of its total shareholders' equity	Positive / negative	Setó-Pamies (2015)
LEV	Tier 1 Capital as percentage of total assets (proxy for the Basel 3 leverage ratio). For European banks only, as Japanese banks do not report this ratio.	Positive	Helfaya and Moussa (2017)
GDP	Gross Domestic Product (GDP) per capita based on purchasing power parity (PPP)	Positive / negative	Fernandez-Feijoo et al. (2014)

3.2 Methodology

In line with the methodology approach of previous studies [37,38,47], the effect of the independent variables on the ESG rating has been tested through panel data analysis to control for omitted and / or unobserved variables. Therefore, a fixed effects (with respect to random effects) model was chosen, as it can also partly mitigate endogeneity issues [37,38,64]. "Natural logarithmic transformations of the numerical (non-index) variables of the age of board members, board size, GDP and bank size have been performed to better approximate a normal distribution and overcome a possible problem of heteroskedasticity" [37,38, p.146]. In line with previous studies [37,38], the OLS fixed effects regression model is estimated as:

$$y = ß_0 + ß_1 X_{i,t} + \varepsilon_{i,t}, \; t=1,2,3,4,5 \qquad (1)$$

"where y is the dependent variable, the ESG rating, $ß_0$ is the constant, the variable X, e.g., the variables of interest, are the different board characteristics as per table 1, ε is independent disturbance, i stands for the individual bank, and t stands for the years covered by the data sample" [38, p. 146]. "Following previous research [37,38,51,61] the OLS fixed effects regression model is complemented by a Hausman's specification test to test whether X is a truly endogenous variable [37]. The respective 2SLS regression model is estimated as follows" [38, p. 146]:

$$x = \alpha_0 + \alpha_t A + \varepsilon_i \qquad (2)$$

"where x is the dependent variable, the ESG rating, α_0 is the constant, the variable A, the different board characteristics as per table 1, ε is independent disturbance, i stands for the individual bank, and t stands for the year covered by the data sample" [38, p. 146].

4 Results

4.1 Descriptive Statistics

Table 2 and 3 show the descriptive statistics for the dependent and independent variables for European and Japanese Banks. The descriptive statistics include the mean, standard deviation, the minimum and the maximum.

The mean of ESG ratings of European banks is 64% and for Japanese Banks 36%. The average ESG score is in line with previous research [37,38] for European Banks. Sustainability expertise on boards shows a mean of 21% in European and 27% in Japanese banks, respectively. Sustainability leadership, e.g., a CEO or Chairperson with sustainability experience, exists with a rather low number of 16% of the European companies in average, but 39% with the Japanese banks. The share of woman on boards and the share of foreigners on boards stand at 16% and 0.4% for Japanese banks, and at 35% and 7% in the case of European banks. The share of woman on boards in European banks remains rather low but seemed to increase compared to previous research findings [37,38], while being even lower in Japanese banks. The average age is 59 years on the board of a European bank and 65 years on the board of a Japanese bank. The proportion of independent directors on boards is 67% for European and is in line with previous research [37,38] and similar for Japanese banks with 69%. In average, 31% of the European banks have a sustainability committee on board level, with 8% of the Japanese banks.

Table 2. European Banks: Descriptive statistics for the dependent and independent variables

Variable	Mean	Standard Deviation	Minimum	Maximum
ESG Rating	0.64	0.14	0.29	0.87
Sustainability expertise	0.21	0.23	0	1
Sustainability leadership	0.16	0.37	0	1
Women on the board of directors	0.35	0.13	0	0.78
Foreigners on the board of directors	0.07	0.09	0	0.5
Age of the board of directors	58.92	3.1	52.5	66.3
Board independence	0.66	0.24	0	1
Board size	14.19	4.14	6	25
Sustainability Committee	0.31	0.46	0	1
Bank size	5.895	1.15	2.9	7.89
Return on equity	2.01	0.89	-3.91	4.67
Leverage	1.77	0.33	0.47	2.58
GDP per capita, PPP	10.47	0.3	10.05	11.49

Table 3. Japanese Banks: Descriptive statistics for the dependent and independent variables

Variable	Mean	Standard Deviation	Minimum	Maximum
ESG Rating	0.36	0.19	0.04	0.79
Sustainability expertise	0.27	0.49	0	1
Sustainability leadership	0.39	0.49	0	1
Women on the board of directors	0.16	0.1	0	0.42
Foreigners on the board of directors	0.004	0.02	0	0.2
Age of the board of directors	65.49	3.1	57.25	71.7
Board independence	0.69	0.13	0.42	0.89
Board size	7.95	2.54	4	13
Sustainability Committee	0.08	0.27	0	1
Bank size	12.51	1.8	8.91	14.76
Return on equity	1.46	0.44	0.08	2.61
GDP per capita, PPP	10.37	0.1	10.21	10.5

4.2 Correlation Results

Table 4 and 5 provide a pair-wise correlation matrix showing important relationships between the main independent variables of the study for both the European and Japanese banks sample. According to previous studies multicollinearity problem occur if the correlation between two variables is higher than 0.9 [37,38].

In the correlation matrix for European banks the highest correlation measured is between board independence and board size; in the case of Japanese banks the highest correlation measured is between foreigners on the board and the existence of a sustainability committee. Therefore, we can conclude that we have no problem of collinearity [65]. The correlations for European banks show that more women on the board, more foreigners on the board, board independence, the existence of a sustainability committee and bank size are associated with higher levels of sustainability experience. Board size is negatively related. In addition, the number of foreigners on the board, the age of the board and the existence of a sustainability committee are associated with sustainability leadership. In the case of Japan, women on the board, board independence and bank size are negatively related to sustainability leadership. Sustainable leadership and the age of the board are positively associated. Sustainable experience is positively associated with sustainable leadership and negatively with board size and bank size.

Table 4. European Banks: Correlation matrix

Variable	SUSTEXP	SUSTLEAD	WBOD	FORBOD	AGEBOD	BODIND	BODS	SUSTCO	BANKSI	ROE	LEV	GDP
SUSTEXP	1											
SUSTLEAD	-.001	1										
WBOD	.461**	-.023	1									

FORBOD	.340**	.157*	.288**	1								
AGEBOD	.160	.417**	.396**	.320**	1							
BODIND	.176*	.118	.232**	.295**	.067	1						
BODS	-.174**	-.092	-.104	-.272**	-.207*	-.541**	1					
SUSTCO	.468**	.197*	.235**	.259**	.320**	.010	.015	1				
BANKSI	.162*	-.087	.153*	.340**	.187*	-.326**	.377**	.178*	1			
ROE	-.021	-.106	-.049	-.031	-.107	.067	-.271**	-.111	-.228*	1		
LEV	.255*	.018	-.142	-.135	.112	-.141	-.047	-.111	-.397**	.087	1	
GDP	-.015	.012	.066	.197**	.^.190	.210*	-.009	.027	.034	.008	-.047	1

[*** p<0.01, ** p<0.05, * p<0.1]

Table 5. Japanese Banks: Correlation matrix

Variable	SUSTEXP	SUSTLEAD	WBOD	FORBOD	AGEBOD	BODIND	BODS	SUSTCO	BANKSI	ROE	GDP
SUSTEXP	1										
SUSTLEAD	.575**	1									
WBOD	.022	-.268**	1								
FORBOD	-.038	-.089	.10	1							
AGEBOD	.166	.231*	.112	.032	1						
BODIND	-.066	-.326**	.338**	.021	.331**	1					
BODS	-.352*	.134	-.207*	.151	-.168	-.241*	1				
SUSTCO	-.131	-.135	.152	.597**	-.030	.132	.323**	1			
BANKSI	-.358**	-.359**	.063	.206*	.182	-.012	.497**	.267*	1		
ROE	-.097	-.090	-.032	.134	-.109	.258*	-.027	.078	-.236*	1	
GDP	.016	0.26	-.439**	-.265**	-.097	-.052	.078	-.220	.011	-.026	1

[*** p<0.01, ** p<0.05, * p<0.1]

The result of the fixed effects regression is presented in table 6. The results show that none of the independent variables of primary interest is statistically significant for European banks. This is contrary to a study in 2020, where a significant positive relationship between sustainability lead and ESG rating could be found [38]. Comparably to the study in 2020, a significant negative relationship between the board size and the ESG rating is shown [38], while in other previous research, a positive relation between board size and ESG performance was found [37].

Table 6. European Banks: Fixed effects regression results

Variable	Regression Coefficient	Robust Standard Error
SUSTEXP	.061	.072
SUSTLEAD	.008	.047
WBOD	.060	.156
FORBOD	-.140	.182
AGEBOD	.408	.367
BODIND	-.066	.074

BODS	-.111*	.063
SUSTCO	.046	.033
BANKSI	-.008	.018
ROE	-.010	.013
LEV	.047	.045
GDP	-.052	.045
Constant	-.200	1.703
R-squared	.206	.122
Regression Model	0.454*	1.727

[*** p<0.01, ** p<0.05, * p<0.1]

In the case of Japanese banks, there are significant negative relationships between sustainability lead (10% significance level), board independence (5% significance level) and ESG performance and significant positive relationships between age and board size and ESG performance.

Table 7. Japanese Banks: Fixed effects regression results

Variable	Regression Coefficient	Robust Standard Error
SUSTEXP	.036	.048
SUSTLEAD	-.123*	.068
WBOD	-.013	.260
FORBOD	1.184	1.082
AGEBOD	1.758**	.564
BODIND	-.382**	.176
BODS	.159*	.085
SUSTCO	-.104	.161
BANKSI	-.015	.016
ROE	.206***	.048
GDP	-.180	.221
Constant	-5.286	3.246
R-squared	.434	.139
Regression Model	0.752***	3.559

[*** p<0.01, ** p<0.05, * p<0.1]

The result of the Hausman's specification test results in an R^2 of .2161 for Japanese banks, with regression coefficients for SUSTEXP and SUSTLEAD of .023 (standard error .054) and -.134 (standard error .077) with statistical significance at the 5% level for the latter. Further, it shows an R^2 of .0574, with regression coefficients for

SUSTEXP and SUSTLEAD of .090 (standard error .044) and .0719 (standard error .028) with statistical significance both at the 5% level for European Banks.

5 Conclusion

For the European banks, the fixed regression model resulted in no, but the Hausman's specification test in a significant relationship between the primary independent variables sustainability expertise and sustainability leadership with the ESG rating. For Japanese banks, the fixed regression shows and the Hausman's specification tests show a negative significant relationship between sustainability leadership on boards and the ESG ratings from Thomson Reuters Datastream.

In summary, data based on the indices EURSTOXX 30 Banks, Topix 17 Banks as well as Thomson Reuters Datastream show mixed results. While European data revealed either no relationships or results supporting the hypothesis that sustainability expertise and sustainability leadership positively impact the ESG rating of the banks, e.g., contradictory results, the results for Japan were rather surprising. The negative relationship between ESG ratings and sustainability leadership might be driven by still rather overall low ESG ratings in Japanese banks, which might be driven by other factors, e.g., lack of coverage, English reporting information and time invested by international ESG rating agencies. The fact that sustainability leadership does not have a positive impact on ESG ratings with the European Banks contradicts previous results [38] is surprising in the context of increased regulatory activity, which might imply an increase in sustainability experienced leadership profiles. However, potentially, the focus is set on other competencies, which can be also observed in die means in Europe versus Japan, with 39% of the banks having sustainability leadership with only 16% in Europe. It is also interesting to see that sustainability expertise on boards is in average higher for Japanese banks than for European banks.

The study might conclude that there is no impact of sustainability expertise on boards on ESG performance of firms. However, further studies could consider including additional ESG rating data providers, such as Morningstar (Sustainalytics), Bloomberg, S&P given the known different ESG rating methodologies applied by the before-mentioned agencies. Also, the data is still limited to a small number of banks in Europe and Japan: The company sample might be expanded to additional banks in Europe and Japan or all stock market listed companies to get additional insights. Potentially, additional and more specific measures of sustainability could be used dependent variable. Also, policymakers can draw insightful lessons learnt from the descriptive statistics found by this study. The fact that Japanese banks show higher means in terms of sustainability leadership and sustainability expertise on their boards might be a useful information for further discussions. In Japan, the rather low ESG ratings could be a source for discussion in the context of the before mentioned initiatives of the TSE and the overall reform process on corporate governance in Japan. In line with some studies, the research could be enhanced by the impact not only on ESG ratings, but also on stock market and financial performance [37] to gain further understanding on potential regulatory measures.

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