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Uta Mathis, Nicole Ondrusch, Dietmar Kilian,
Alexander Redlein, Klaus Turowski, Stefan Weidner, Holger Wittges (Hrsg.)

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Technische Universität Wien
Fakultät für Maschinenwesen und Betriebswissenschaften
Institut für Managementwissenschaften
Forschungsgruppe Immobilien und Facility Management
SAP Academic Competence Center
Resselgasse 5, 1040 Wien

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VORWORT

Nachhaltigkeit hat in den letzten Jahren stark an Bedeutung gewonnen. Dies wurde nicht nur durch die Konsumenten getrieben, die immer mehr Wert auf Güter legen, die im Einklang mit der Umwelt produziert werden, sondern auch durch diverse Gesetzgebungen wie die EU-Taxonomie, die CSRD und ESRS der EU. Diese fordern unter anderem im Bereich der nicht-finanziellen Berichtserstattung von Unternehmen gesicherte Informationen über deren Energieverbrauch und den CO2-Fussabdruck. Damit aber nicht genug, es wird auch gefordert, dass Unternehmen bis 2050 CO2 neutral agieren und die notwendigen Maßnahmen in diesen Berichten dokumentieren. Aber nicht nur in der EU gibt es derartige Regelungen auch in Teilen der USA, Südafrika und Indien. Das IFM der TU Wien beschäftigt sich nun seit über 15 Jahren mit dem Thema Nachhaltigkeit vor allem im Bereich Immobilien, da sie für rund 40% des CO2 Ausstoßes weltweit verantwortlich sind. In den letzten Jahren wurden daher vor allem in Kooperation mit der Stanford Universität viele Bereiche erforscht, wie die effiziente und kostengünstige Nachrüstung von Bestandsgebäuden für ESG-Monitoring, Sicherstellung der neuen Datenqualität für die nichtfinanzielle Berichterstattung und Möglichkeiten der Dekarbonisierung des Gebäudebestandes. Da das IFM dieses Jahr der Host der SAP Academic Community Conference ist und sich das IFM und auch die restlichen Stakeholder wie die SAP SE intensiv mit diesem Bereich beschäftigen, wurde gemeinschaftlich das Motto „Innovation to Foster Sustainability“ gewählt.

Unser Ziel als Veranstalter dieser Konferenz ist es, unsere Partner im SAP University Alliances Programm auf kommende Herausforderungen im Bereich Zusammenspiel neue Technologien, Nachhaltigkeit(sberichterstattung) und Dekarbonisierungsmaßnahmen vorzubereiten. Wir möchten sie enablen, durch neue Methoden der Wissensvermittlung im Bereich ERP und Nachhaltigkeit, aber auch durch Austausch von Forschungsergebnissen und vor allem durch internationale Vernetzung ihre Studenten gezielt auf die neuen Herausforderungen vorzubereiten und durch geeignete Fachkräfte auch den Wirtschaftsstandort EU zu stärken.

Die SAP Academic Community Conference 2024 (D-A-CH) (SAP ACC2024) steht daher in diesem Jahr unter dem Motto „**Innovation to Foster Sustainability“** (dt.: Innovation um Nachhaltigkeit zu fördern). Dieses Motto wird in den folgenden fünf Themengebieten vertieft: „Neue und innovative Lehrmethoden zur Vermittlung der notwendigen Kompetenzen“ (Track 1) sind ebenso Gegenstand, wie der Umgang mit fortschrittlichen Technologien (Track 2). Neben dem Themengebiet „Environment Social Governance (ESG), Kreislaufwirtschaft und Nachhaltigkeit“ (Track 4) bietet die SAP ACC2024 auch die Möglichkeit zum Austausch zu „Big Data und Analytics mit SAP – Gewinnung verlässlicher Informationen durch Datenanalyse“ (Track 3).

Die Veranstaltung bietet neue Impulse und wertvolles Fachwissen, lässt aber auch Raum für Austausch und inhaltlichen Diskurs. Jeder Track bietet didaktische, wissenschaftliche und praxisorientierte Beiträge und Diskussionen mit FachexpertInnen. Die Tracks bieten DozentInnen, ForscherInnen und PraktikerInnen ein gemeinsames Forum, um sich im Kontext der Gestaltung, Nutzung und des Betriebs komplexer Anwendungssysteme über Einsatzszenarien und Erfahrungen von SAP-Lösungen in Lehre und Forschung auszutauschen. Methodisch stehen didaktische, technische und organisatorische Innovationen und

Herausforderungen sowie deren Umsetzung mit praktischen Anwendungsbeispielen im Fokus. Bewährte und neue Lösungen werden vorgestellt und besprochen.

Für insgesamt zehn Themengebiete (Tracks) wurde zur Einreichung von folgenden Beitragsarten aufgerufen: wissenschaftliches Paper (8-10 Seiten), wissenschaftliches/praktisch orientiertes Short-Paper (3-5 Seiten), rein praktisch orientierte Präsentation (bis zu 15 Folien). Bereits zuvor publizierte Beiträge wurden nicht akzeptiert. Wir erhielten 28 Einreichungen, die alle im Single-Blind-Peer-Review begutachtet wurden und von denen wir nach Überarbeitung 25 Beiträge akzeptiert haben.

Darüber hinaus wurde im Rahmen der Konferenz ein Workshop zu den Thema Internationalisierung angeboten**.**

Ihre

Uta Mathis *Nicole Ondrusch* *Dietmar Kilian*
Alexander Redlein *Klaus Turowski* *Holger Wittges*
Stefan Weidner

zusammen mit dem Organisationsteam der ACC 2024 (D-A-CH)

Wien, im September 2024

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TRACK 1: NEUE UND INNOVATIVE LEHRKONZEPTE ZUR VERMITTLUNG DER NOTWENDIGEN KOMPETENZEN

Track Chairs: Prof. Dr. Cordula Boden, Prof. Dr. Dietmar Kilian

Towards a Next-Generation Data Center Curriculum: Utilizing Containerization for Teaching SAP HANA on IBM Power

Maximilian Niedermeier[1], Wolfgang Rother[2], Dilser Ünsal[1] & Holger Wittges[1]
[1] TUM School of Computation, Information and Technology, Garching, Germany
[2] IBM Deutschland GmbH, Böblingen, Germany

Abstract: There is a current trend for ERP customers to utilize hybrid cloud computing. However, ERP curricula are often limited to the end-user perspective and do not address the management of the underlying infrastructure. Aiming to prepare future SAP business users to successfully navigate modern IT landscapes, we propose a curriculum draft teaching hybrid cloud technologies for SAP applications. To be more precise, our research shows summaries of our first curriculum modules and goes into detail of how to implement the teaching environment which is based on containers. Afterwards, we evaluate our course and mention which teaching units we plan in the future.

Keywords: Curriculum Design, Higher Education, Hybrid Cloud, Containerization, SAP HANA

1. Introduction

When it comes to hybrid cloud computing, research shows that there are various open challenges (Khan & Ullah 2016). Seifert et al. (2023) consider a human dimension as one factor for the uncertainty in technical service design of hybrid clouds. This claim refers to another article (Rockmann et al. 2014) which states that employees need proper training for being able to successfully integrate and manage cloud systems. As shown by examples such as (Jararweh et al. 2013) or (Murah 2012), teaching cloud computing also found its place in research. Together with IBM, the SAP UCC Munich aims to contribute to this research field by developing an own hybrid cloud curriculum specifically tailored for the administration of SAP software.

A hybrid cloud infrastructure consists of at least two different cloud deployment models (Mell & Grance 2011). For example, it could describe a private cloud which is hosted on-premise and uses several public cloud services as functional expansions. For both on-premise and cloud computing, virtualization is the base technology. Therefore, gaining knowledge in this topic helps to understand basic concepts of cloud computing and prepares learners for working with both hyperscaler infrastructure, small server landscapes or the integration of both. Another goal of our project is to bring SAP end users closer to the underlying technologies. Additional knowledge in infrastructure management could be helpful in setting up, maintaining or fixing SAP solutions.

In April 2024, we conducted a test run for some of our curriculum modules. The modules teach various administration skills required for working in a hybrid cloud environment for SAP solutions. Our paper aims to provide an initial assessment of our teaching methods and also provides guidance on creating our innovative computing environment, which allows each student to work with an isolated database instance.

2. Course Design

Although we plan to cover a broader range of topics in the future, the goal of our pilot test was to check the necessary time consumption for our hands-on programming tasks. Tab. 1 summarizes the five modules which we introduced to the learners. Students did not require any prior knowledge.

Tab. 1: Content summaries of our five workshop modules.

Module	Summary
(00) *Introduction to Hybrid Cloud Environments*	Participants explore the foundations of cloud computing with an emphasis on different depoyment models such as private, public or hybrid clouds. They also learn about various service models and the advantages and difficulties of working in hybrid cloud landscapes.
(01) *IBM Power Virtualization at SAP UCC Munich*	In this module, the students learn about the virtualization technologies for IBM Power architecture. They gain knowledge about processor, memory, network and storage virtualization including Virtual I/O Servers (VIOS).
(02) *Linux Fundamentals*	In this chapter, we introduce learners to essentials of Linux administration focusing on SAP setups. As a hands-on exercise, the students establish a connection to our IBM PowerE1050 servers and gather first experiences with Unix shell scripting and system monitoring.
(03) *Streamlining Operations via Containerization and Automation*	This module covers microservice architectures and practical containerization topics such as the transition from Containerfiles to images and containers. As a hands-on task, students face a faulty Containerfile which they have to patch and thereby prepare for a SAP HANA Express installation. Our motive behind this topic is to bring students closer to an own SAP HANA Express setup which they could also run on their own notebooks.
(04) *SAP HANA Database Deployment*	Finally, participants learn about the features of the SAP HANA in-memory database. Afterwards, each student has to install an own instance of the SAP HANA Express edition in a SAP-ready container. We also explain how to connect to the containerized databases via SAP HANA Studio. Finally, we prepare some database adminstration exercises such as SQL-based analyses, user management and monitoring important memory metrics.

3. Implementation

Based on the idea of a whitepaper utilizing Red Hat OpenShift for containerizing SAP applications (Rank et al. 2023), we decided to create containerized learning environments for SAP HANA administration using Podman. To be more precise, we created a SAP-ready image which we could distribute to the learners. The participants could then log-in to a shared Red

Hat LPAR running Podman and create their own container based on this image. In this container, they were to install and work with the SAP HANA Express Edition, which is a free version of SAP HANA limited to 32GB of RAM. Fig. 1 shows an overview of our virtualization setup:

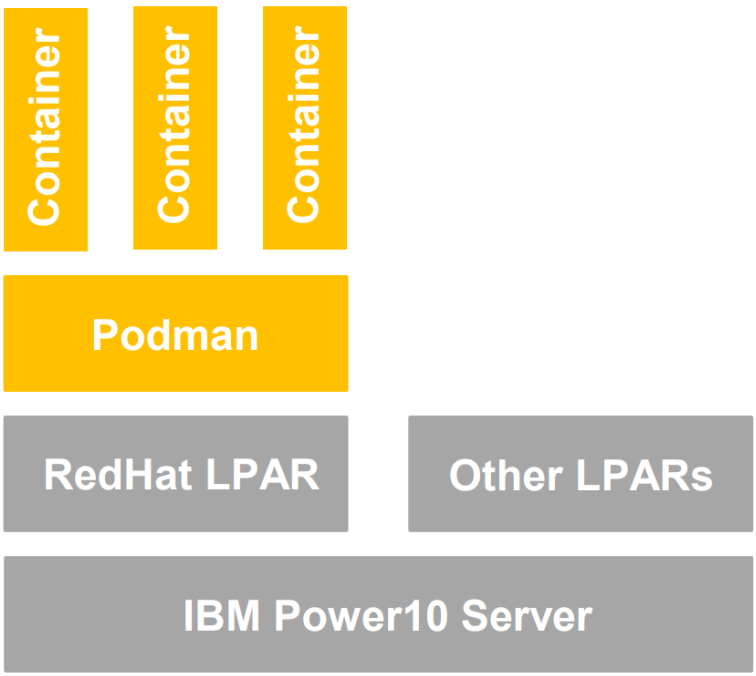

Fig. 1: Our teaching environment consisting of several containers each being able to run SAP HANA Express.

Working with IBM Power10 servers and the IBM Power architecture *ppc64le*, we first had to create our own Containerfile as we could not find an existing image on the internet. Our Containerfile uses a *Red Hat 9.2* base image and copies all SAP HANA Express installation files to the resulting image. Afterwards, we iteratively tried to install the SAP HANA Express server in a running container and always inspected the error messages inside the SAP log files *hdbinst.log* and *hdblcm.log*. In accordance to the error messages, we adjusted the Containerfile and installed missing packages. We were able to run a successful server installation when including the following packages: *libxcrypt-compat*, *chkconfig*, *iproute*, *libaio*, *libatomic*, *numactl-libs*, *libtool-ltdl*, *procps-ng*, *ncurses* and *hostname*. Fig. 2 illustrates this procedure:

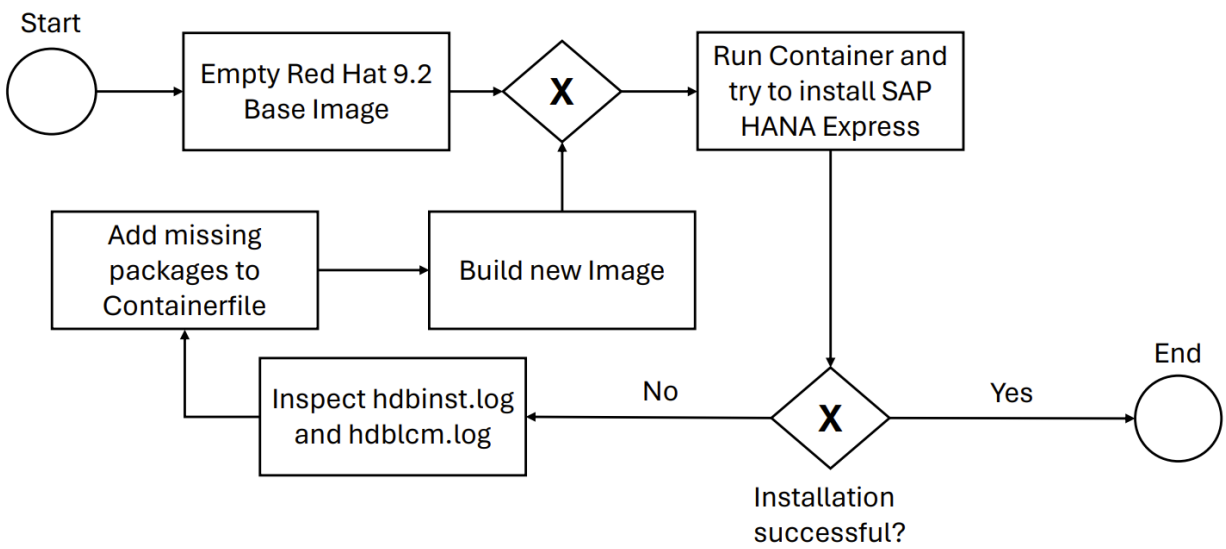

Fig. 2: Our approach to create a Containerfile ready for running the SAP HANA Express server.

As described in section 2, we included some errors in the final Containerfile and let the students patch it while working through module 3. In module 4, we provided each student an image based on the correct Containerfile which already included all required packages for SAP HANA Express. Then, we let the students create a container and install the database manually. When connecting to SAP HANA Express via SAP HANA Studio, it is important to open required ports for the running container. The port numbers are dependent on the instance number of the database: The system database port is *3<Instance-Number>13* (e.g. 30113), whereas the tenant database port is *3<Instance-Number>15* (e.g. 30115). When adding the database to the system list in SAP HANA Studio, it is necessary to use the following syntax *<Podman_LPAR>:<Port>* for the host name.

There are several reasons why we chose to let the students install SAP HANA Express on containers: First, each learner can work in an isolated environment, even though we only use a single LPAR for teaching. Next, if a learner makes a mistake during the workshop, containers allow fast re-deploys to a certain deployment state. Finally, after the workshop, we simply need to delete the containers. There is no need to re-deploy several LPARs for a new workshop.

Apart from using our container solution for teaching, companies could also follow our approach and create their own SAP-ready container for testing and development purposes. Fast container re-deploys would allow database administrators to run risk-related operations (such as load tests or simulations of system shutdowns) in an isolated environment.

4. Course Evaluation

In addition to the two lecturers, a total of 9 participants took part in the pilot test for our curriculum modules. The learners came from different backgrounds such as computer science, information systems, physics and robotics. Before and after the event, we provided the students a voluntary survey to better understand the learning success of our teaching units. This survey was completed by 6 out of our 9 participants. All survey answers were based on a 4 point Likert scale ranging from 1 to 4. Tab. 2 shows the questions and the averaged answer values before and after the event.

Tab. 2: Survey questions and average answer values for evaluating the learning success of the participants.

Module	Question	Avg. (before)	Avg. (after)
(00)	I am aware of the different cloud deployment options available in the market.	2.33	3.17
(00)	I am aware of the different cloud service models available in the market.	2.33	3.00
(00)	I am aware of the benefits as well as the challenges related to hybrid cloud environments.	1.67	3.17
(01)	I understand basic PowerVM concepts, such as memory, network or storage virtualization.	2.33	3.50
(01)	I understand the role of IBM Power hardware when deploying SAP products.	2.17	3.33
(01)	I feel confident working with IBM Power hardware in the future of my career.	2.00	3.00
(02)	I am aware of the typical Linux system administration tasks.	2.67	3.67
(02)	I have experience working with the Unix shell / Red Hat commands.	2.83	3.50
(02)	I feel confident in solving Linux scripting tasks in the future of my career.	2.50	3.33
(03)	I am aware of the difference between a virtual machine and a container.	2.17	3.17
(03)	I know what a Containerfile, an Image and a Container is.	2.00	3.67
(03)	I feel confident in solving containerization tasks in the future of my career.	1.83	3.33
(04)	I am aware of the typical SAP HANA database administration tasks.	2.00	2.67
(04)	I know how to solve basic SAP HANA database administration tasks.	1.83	2.17
(04)	I feel confident in solving database administration tasks in the future of my career.	2.00	2.33

A simple analysis shows that following the workshop, ratings for each of the questions increased. This implies that the first draft of our curriculum modules already shows desired effects. It is important to mention that due to time restrictions and our goal to finish all units in a single day, participants could not finish the last module in its entirety. This issue affects the reliability of the evaluations for this particular chapter.

Qualitative feedback also confirmed the workshop's effectiveness. Many students gave feedback of how the learning materials had changed their perspective on the subject matter. In the following, we quote two of the participants who agreed to summarize their own perception of the day:

„*The workshop provided comprehensive practical insights about the software infrastructure for an SAP system on an IBM Power server. The introduction to modern cloud system architectures, relevant services and real-life business cases was a beneficial new learning experience for me*."

„*In the course I learned a lot about different cloud models and especially the functionality of hybrid clouds. The broad background knowledge of the lecturers and interactive tasks in between helped me to understand the topic more deeply*."

5. Future Work

As a next step, we plan to expand our test run and build a two-day workshop. Thereby, we not only aim to improve our current modules but also add new modules to the course. Considering new modules, we plan to explain automated installations via Infrastructure-as-Code (IaC) using Ansible playbooks as well as the connection between on-premise landscapes and Software-as-a-Service (SaaS) products. When it comes to improving our existing modules, we will provide a showcase of PowerVC which greatly simplifies the virtualization of IBM Power landscapes. Also, we are working on teaching advanced containerization technologies such as Kubernetes and Red Hat OpenShift. Finally, we will show how to achieve high availability in SAP HANA database systems. In the following, we provide a short summary of our future workshop consisting of two days:

- Day 1:
  - Introduction to Hybrid Cloud Environments
  - IBM Power Virtualization at SAP UCC Munich (incl. PowerVC)
  - Fundamentals of Red Hat Enterprise Linux
  - Automation 1: Streamlining Operations via Containerization (incl. Kubernetes and Red Hat OpenShift)
- Day 2:
  - Automation 2: Infrastructure-as-Code (IaC) at the Example of Ansible
  - SAP HANA Database Administration (incl. high availability)
  - Connecting On-Premise and Cloud Services: A Practical Approach

Lastly, we were provided a stand-alone Red Hat curriculum which goes into detail with teaching Ansible for SAP HANA. This curriculum contains additional three days of learning materials and could extend our workshop by deep diving into IaC topics.

6. Conclusion

This practical-oriented research contribution shows how to structure and set up a successful learning environment for SAP HANA administration on IBM Power servers. We introduce the contents of suitable curriculum modules, explain how to use containerization for teaching and finally evaluate our approach. We provided the same survey before and after the event and find that for each question, the averaged answer value raises. In the future, we plan to revise and

further extend our workshop. For example, we plan to connect on-premise landscapes to SaaS products and also include new technologies such as the Red Hat products Ansible, Kubernetes or OpenShift. We believe it is important to continue our research about the teaching of SAP administration which gives business users insights into the technical background of the tools they use on a daily basis.

7. Acknowledgements

We would like to express special thanks to the IBM manager Alexander Loibl who played a major role in making this curriculum possible. Also, we would like to thank Benjamin Greif for his active participation in designing this course and providing scientific assistance.

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Simulation Game Based Teaching of Value Stream Analysis and Design with Multimodal Large Language Models (MLLMs) Assistance

M. Geisthardt, L. Engel & J. Marx Gómez
Carl von Ossietzky University of Oldenburg, Oldenburg, Germany
Jade University of Applied Sciences, Wilhelmshaven, Germany

Abstract: Value stream analysis and design are pivotal elements of lean management, widely employed by industrial improvement teams to facilitate resource-efficient value creation. Increasing data volumes and complexity, along with methodological advancements are prompting a reevaluation of how improvement teams should learn, think, and operate. Consequently, novel pedagogical approaches for educating students and professionals are required. Current research has not yet resulted in a suitable solution that imparts the methodological complexity of value stream analysis and design in a motivating and engaging fashion. To address this gap, this paper presents the application of gamification in combination with the CRISP-DM to develop and test a simulation game prototype called "North Star – The Value Stream Game". Integrating game-based learning with multimodal LLMs into the game process, the simulation game enables innovative teaching and learning of value stream analysis and design, with a focus on identifying resource-efficient optimization strategies.

Keywords: Value Stream Analysis and Design, Simulation Games, Game-based Learning with Artificial Intelligence, Multimodal Large Language Models, Resource-Efficient Thinking

1. Introduction

In industrial settings improvement teams have the responsibility to optimize value creation and eliminate waste by utilizing globally established lean management tools like value stream analysis and design (Rother & Shook 2011). Due to rising data volumes and complexity in industry, as well as advancements of the methodology, the way improvement teams learn, think, and operate needs to adapt. Thus, novel solutions for educational training of students and professionals are required. It is well-known that traditional expository lectures lack efficiency regarding knowledge retention and engagement. Applying gamification in formal education yields significant positive effects on cognitive, motivational, and behavioral learning (Huang et al. 2020, Sailer & Homner 2020). Current research has applied gamification to cultivate understanding of several facets of lean management (Bloechl et al. 2017, Bárdy et al. 2014, Gomes et al. 2013). These efforts have not yet resulted in an approach that successfully conveys the methodology of value stream analysis and design in a motivating and engaging fashion. To fill this gap, this paper presents the employment of gamification jointly with the Cross Industry Standard Process for Data Mining (CRISP-DM) to prototype and test a simulation game called "North Star – The Value Stream Game" (Werbach & Hunter 2020, Wirth & Hipp 2000). Through utilization of game-based learning with Artificial Intelligence (AI) a tailored multimodal large language model (LLM) called "NorthStarGPT" can act assistive, cooperatively, or even competitively within the game process creating a unique hybrid (physical and digital) form of learning accounting the aspects personalization, adaptive feedback, content creation, and analysis and assessment (Yu & Glazieva 2022).

This paper initially introduces the theoretical background of the simulation game and the methodology which leverages gamification and the CRISP-DM. Subsequently, the current simulation game prototype and its multimodal LLM integration are presented briefly. Lastly, a conclusion and an outlook on future research is offered.

2. Theoretical Background

2.1. Value Stream Analysis and Design

The abstract construct called (end-to-end) value stream can be defined as a process chain including all value adding and non-value adding activities that are essential for the main flow of a company's products from sourcing to the customer (Rother & Shook 2011). Within application of value stream analysis and design, an improvement team maps the current value stream of a relevant product family and illustrates it using standardized value stream elements (value stream analysis) (Rother & Shook 2011). Wastes can be identified using the concepts of "muda", "mura", and "muri" (Ohno 2013). By eliminating the identified wastes and applying the value stream design guidelines, the improvement team designs a resource-efficient target value stream that is optimized in terms of lead time (value stream design) (Erlach 2010). The ubiquitous guideline for all activities is the ideal state known from the Toyota Production System (TPS). Also referred to as the "north star" it incorporates the aspects zero defects, 100 % value creation, one-piece flow on customer demand, and safety for the people (Rother 2009). Inspired by the philosophical ideal state of the TPS, this paper's simulation game is referred to as "North Star – The Value Stream Game". The corresponding multimodal LLM component of the simulation game is called "NorthStarGPT".

2.2. Game-based Learning with Artificial Intelligence

Games are voluntary and organized activities with objectives and rules, either physical or mental, for competition, education, or entertainment. Simulation games, a specific game category, uses simulated environments to teach and experiment with or within real world systems (Wixon 2015). Gamification is the process of incorporating game mechanics and strategies into non-game environments to engage and encourage players. To increase interest and participation, it utilizes scoring systems, leaderboards, and awards (Brauer et al. 2019, Schmidt et al. 2015).

Game-based learning with AI is an educational technique that combines AI with interactive games to elevate the overall learning process. Giving users an intense and individualized learning experience, this approach blends fun and motivational aspects of games with intelligence and adaptability of AI. Objective is to encourage engagement, problem solving, critical thinking, and knowledge retention to make learning more enjoyable and effective (Yu & Glazieva 2022). Core elements of game-based learning with AI are personalization, adaptive feedback, content creation, and analysis and assessment (Ma et al. 2022).

3. Methodology

To develop the simulation game called "North Star – The Value Stream Game" and test its ability in teaching value stream analysis and design to students and professionals, the six steps to gamification approach by Werbach and Hunter and the CRISP-DM by Wirth and Hipp are

applied jointly (Werbach & Hunter 2020, Wirth & Hipp 2000, Schröer et al. 2021). CRISP-DM is applied in big data and data science, developing solutions that deal with large data sets and probabilities – aspects that also occurs in simulation games (Geisthardt et al. 2023b). Contrasting traditional gamification frameworks such as mechanics-dynamics-aesthetics (MDA) or octalysis, this joint application of gamification and the CRISP-DM offers a cyclical information technology (IT) oriented approach that provides a seamless development flow (Chou 2019, Hunicke et al. 2004). Within simulation game development, a multimodal LLM (in this case GPT-4o by OpenAI) called "NorthStarGPT" is tailored via knowledge modeling and prompt engineering. The multimodal LLM is integrated into the game process to elevate learning through acting guiding and assistive, collaborative, and competitive. The simulation game is tested after development within the "Industrial Engineering" lecture with 16 master students at the Jade University of Applied Sciences.

4. Results

The simulation game "North Star – The Value Stream Game" focuses on the objective of teaching players value stream analysis and value stream design as realistically as possible in a playful way. Thereby, players are enabled to learn the methodology by experimenting with different individual value streams. The overriding objective of the simulation game is to convey methodological knowledge in a motivating and engaging way while at the same time explicitly promoting the development of resource-efficient strategies (in value stream design) and promote resource-efficient thinking. Player‘s target behavior within the simulation game involves applying value stream design guidelines to design and model optimized target value streams towards the "north star" – including understanding the implications across a variety of scenarios while strategically deploying limited resource units. It is crucial that the target group, consisting of students and professionals with an affinity for lean management, not only understands the methodology, but can also comprehend the real-world complexity. Thus, players are enabled to implement the concept of value stream analysis and design over the long term to achieve superior improvements.

The simulation game objectives, the target behavior of the players, and the player characterization, are scoped within a five-step process of the simulation game illustrated in figure 1.

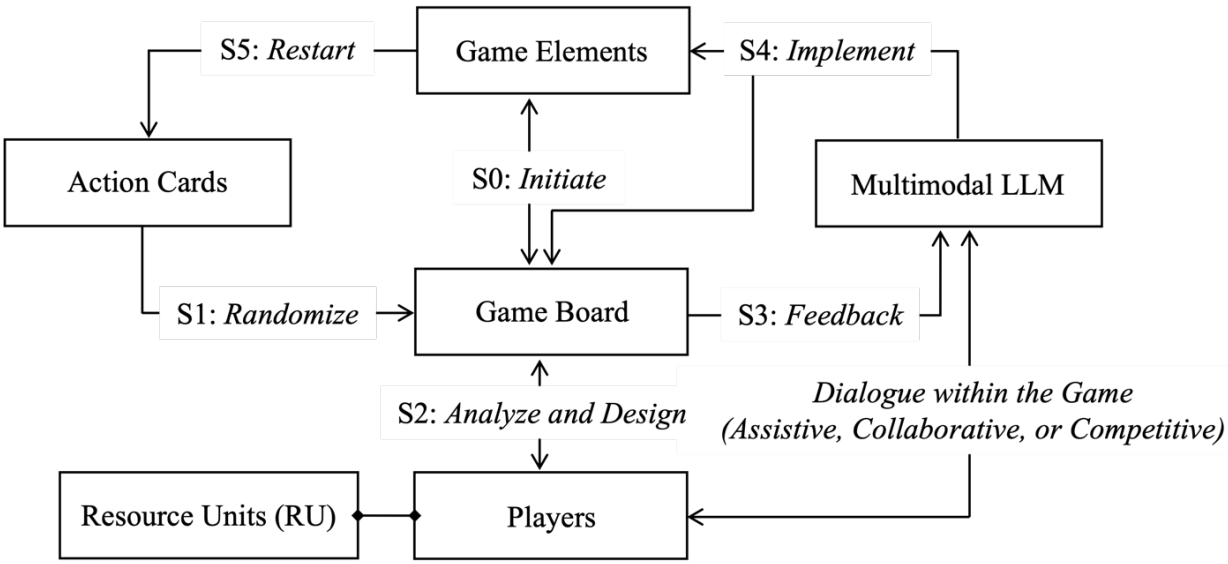

Fig. 1: Five-Step (S1 to S5) Structure of "North Star – The Value Stream Game" (Geisthardt et al. 2023a).

At the beginning of the simulation game, a value stream is build up on the game board (whiteboard) based on a pre-made situation description (story). This is carried out with game elements from value stream analysis and design. The value stream represents the story's production system and is considered as analysis and design object (S0: *Initiate*). Once the simulation game is initiated, the multimodal LLM is initiated. This involves informing the LLM of the situation description, the value stream, the number of players and the desired mode via a multimodal dialog. Three modes are available. In assistive mode, the multimodal LLM accompanies and guides the game process. In Collaborative mode, the multimodal LLM can additionally be consulted about the value stream and the action cards during the game process. In competitive mode, the multimodal LLM can be deployed as an opponent with different difficulty levels.

Next, the player's figures are placed at the starting point on the progression stairs and each player receives 10 resource units, which they can invest in value stream design during the five rounds of the simulation game. The action card deck (22 action cards) is then shuffled, and five cards are randomly dealt to each player (S1: *Randomize*). The action cards represent value stream design guidelines, including name, resource cost, and modification instructions in case of activation. Players keep their cards secret, creating elements of uncertainty and competition.

Within analysis and design, players strategically choose which action card they want to activate and display face up considering the present value stream and their available cards (S2: *Analyze and Design*). Each player can only activate one card per round and pays the resource unit cost for the activation. Depending on the combination of the value stream and the action cards being played, the multimodal LLM determines individual rewards on a scale from +5 (very good) to -5 (very bad) (S3: *Feedback*). The player with the highest round reward wins the current game round and can advance one step closer to the "north star" on the progression stairs and receive their resource units as a return on investment. The value stream design guideline associated with the card of the player who wins the round is implemented into the existing value stream by using modification instructions from the action card and value stream elements (S4: *Implement*). Lastly, the action cards are collected, and the game process starts again from step one (S1) for following consecutive four rounds (S5: *Restart*).

To give insight into the testing of the simulation game, the following figure 2 shows the application of the simulation game in the lecture “Industrial Engineering” with 16 master students of the degree program “Engineering and Management” at Jade University of Applied Sciences. The integration of the multimodal LLM called “NorthStarGPT” was employed in assistive mode to guide the game process. The game was played based on a fictitious prepared scenario using the example of photovoltaic cell production. The game was supervised by a human game master with an additional human observer to capture the experience, reactions, and opinions of the players.

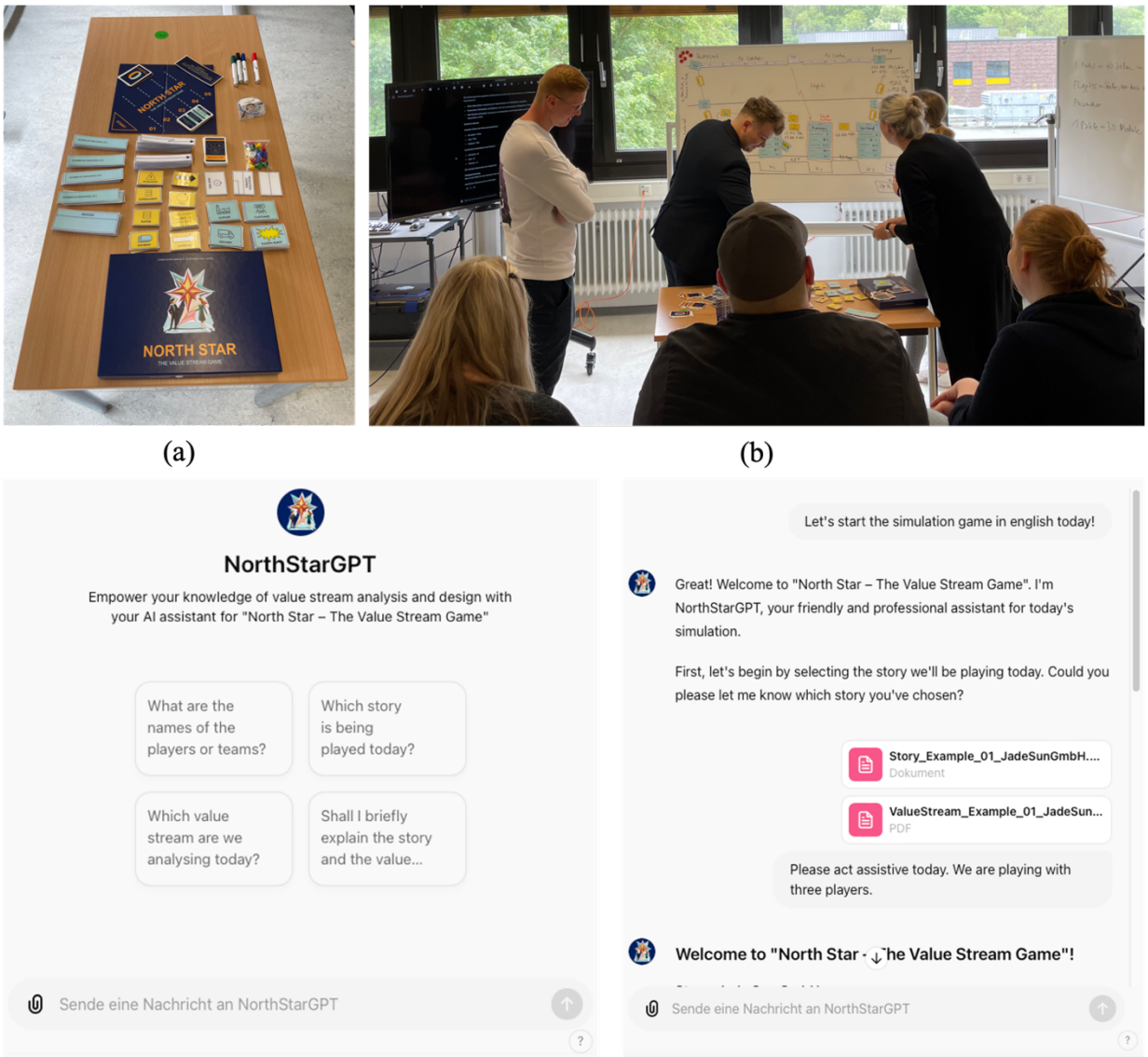

Fig. 2: Testing “North Star – The Value Stream Game” and “NorthStarGPT” within the Lecture “Industrial Engineering”. (a) Game Components: Game Box, Game Elements, Action Cards, Progression Stairs, Resource Units, and Evaluation Cards. (b) Testing: Game Board with Game Elements and multimodal LLM Running on TV for Dialogue within the Game. (c) Welcome Page for the Interactive Dialogue with the Multimodal LLM “NorthStarGPT”. (d) Multimodal Dialogue with “NorthStarGPT” within the Initiation Phase of the Simulation Game.

While at the beginning of the game the students were skeptical about the added value of learning through the simulation game, increasing enthusiasm, motivation, and commitment could be observed during the game – even among less involved students. After 90 minutes of gameplay, the final feedback revealed that the simulation game enabled the students to develop a deeper understanding of value stream analysis and especially the practical application of value stream design. The students also understood and applied the aspect of resource-efficiency. The students identified high potential in the utilization of the game in workshops in real companies. Further development of the game will require work on the stability of the technical setup.

5. Conclusion and Future Work

This paper presented the development and test of a simulation game called "North Star – The Value Stream Game" with game-based learning with a multimodal LLM called "NorthStarGPT". The game was realized through the joint application of gamification and CRISP-DM. Aim of this simulation game is to teach students and professionals the complex methodology of value stream analysis and design using AI – and thus deviate from inefficient courses. The AI component of the simulation game is a tailored multimodal LLM (GPT-4o from OpenAI), which can be used in three modes: assistive, cooperation, and competition. Following its development, the simulation game with multimodal LLM was tested with 16 master's students at the Jade University of Applied Sciences as part of the "Industrial Engineering" lecture. Using the simulation game jointly with the multimodal LLM in assistive mode it could be observed that the students showed increasing motivation and engagement in addition to learning identifying resource-efficient optimization strategies in value stream design. In the continuation of this research, the other two modes of the multimodal LLM are evaluated in more detail. Also, the simulation game will be extended by the advanced forms of value stream analysis and design including aspects such as material flow cost accounting (Engel & Kranhold 2021) and information logistics (Meudt 2020).

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Bridging the Gap: Integrating SAP Security Services into Cybersecurity Education at FH Aachen – University of Applied Sciences

Thorsten Weber[1] & Georg Neugebauer[2]
[1]SAP SE, 40882 Ratingen, Germany, [2]FH Aachen, 52066 Aachen, Germany

Abstract: As the digital landscape evolves, so does the complexity of cyber threats, underscoring the need for skilled cybersecurity professionals. This study focuses on integrating SAP's Authorization and Trust Management Service (XSUAA) into the cybersecurity curriculum at FH Aachen - University of Applied Sciences. This strategic move aims to improve practical skills and streamline training for employers. A mixed methods evaluation showed moderate student enthusiasm, with interest and perceived career relevance scoring 3.8 and 3.65 out of 5, respectively. However, students struggled with basic concepts, scoring an average of 2.47 out of 5. Feedback called for more hands-on experiences and better access to resources. These insights have led to curriculum revisions that better integrate theory with practical application using real-world tools such as SAP's XSUAA. Such improvements are critical to preparing students for immediate entry into the workforce and enhancing graduates' employability in the dynamic field of cybersecurity.

Keywords: Cybersecurity Education, SAP Security Services, Curriculum Integration, XSUAA, Workforce Readiness.

1. Introduction

In cybersecurity, there is a significant gap between industry needs growth and skilled professionals' availability (OECD, 2023). As industries become more digitized, the complexity and volume of cyber threats increase, requiring a large and highly skilled workforce. Cybersecurity roles often necessitate a deep understanding of technical systems and substantial prior experience, even at the entry-level (John et al., 2020; OECD, 2023). The urgent need for immediate contributions post-hire drives organizations to seek professionals who require minimal training, underscoring the importance of targeted, practical training programs in educational settings (Kirwan & Balachnadran, 2019; Shen et al., 2023). This paper discusses integrating real-world security solutions, such as SAP's Business Technology Platform, into cybersecurity curricula at the FH Aachen - University of Applied Sciences. Such integration enriches the educational experience and prepares students effectively for the workforce, especially in critical areas such as authentication and access management technologies (Dutta et al., 2022).

This study outlines developing and assessing a hands-on cybersecurity curriculum at FH Aachen, designed to bridge academic learning with industry needs using SAP security technologies. This revised curriculum aims to shorten the training period for new employees, enhance students' practical understanding, and prepare them for immediate employment, thereby boosting their contributions to cybersecurity and economic sectors.

2. Introduction to the SAP Business Technology Platform and SAP Extended Services for User Account and Authentication

The SAP Business Technology Platform (SAP BTP[1]) is an integrated development environment that equips companies with the tools to develop, manage, and optimize applications in a cloud environment. It consolidates various services, including database management, application development, and integration into a cohesive platform. This unified approach significantly aids digital transformation by enabling companies to innovate without the burdens of managing different systems. The SAP Extended Services for User Account and Authentication (XSUAA[2]) is a crucial security component within this platform. XSUAA acts like a digital gatekeeper, managing secure access and permissions for applications deployed on SAP BTP. It enhances security by managing roles, scopes, and role collections that specify user permissions within SAP BTP applications.

Integrating XSUAA entails setting up a security profile in JavaScript Object Notation (JSON) format and detailing roles, scopes, and role collections. Upon application access, XSUAA authenticates the user's credentials against an external identity provider (IdP), checks the user's roles, and issues a digital token representing the user's access rights.

2.1. FH Aachen Cybersecurity Curriculum

The Bachelor of Computer Science at FH Aachen focuses on IT security through a combination of mandatory and elective modules. The mandatory module, "Data Networks and IT Security," is the baseline for the focus area of cybersecurity, providing the basics in network and information security. The module is part of a series of mandatory modules within computer science in the first three semesters of the curriculum.

In the following two semesters, students can choose from various elective modules to deepen their knowledge in specific areas of cybersecurity. These elective modules include, among others, "IT Security 2" and "Web Application Security," "DevSecOps," and "Security by Design & Secure Coding." The bachelor's thesis in cybersecurity is the final part of the curriculum. There is also a master's degree in computer science with further elective modules in cybersecurity. However, we focus on the bachelor's program because most students pursue a bachelor's degree, and most elective modules in cybersecurity are within the Bachelor's curriculum.

This comprehensive cybersecurity curriculum equips students with the necessary skills and knowledge to master the challenges in the field, preparing them for advanced professional roles and challenges in the industry.

[1] https://www.sap.com/products/technology-platform.html
[2] https://docs.cloudfoundry.org/concepts/architecture/uaa.html

2.2. Focus on Authentication and Authorization in the Module "Security by Design & Secure Coding"

Authentication and Authorization are central topics in the "Security by Design & Secure Coding" module, led by Prof. Dr. Georg Neugebauer. The module introduces these topics, focusing on contemporary technologies such as OAuth 2.0[3] and OpenID Connect (OIDC[4]), which are essential for API-based services on the internet. The practical component includes exercises and lab work on a demo application - a cloud photo printing service that interfaces with a user's cloud data storage using CRUD-based authorization scopes. Basic access authentication and an OIDC flow via GitHub enhance practical training. Despite these practical insights, the application of these technologies in real-world production environments remains underexplored, highlighting a potential area for enhancement in the curriculum.

3. Related Work

Integrating SAP into academic curricula is becoming increasingly recognized as a crucial step in aligning education with the evolving demands of the cybersecurity industry. The collaborative efforts between SAP Labs and the Birla Institute of Technology and Science-Pilani exemplify the significance of integrating real-world applications to enhance learning outcomes (Carmichael et al., 2018; Gopal & Nagpal, 2022). Colvin and Carmona (2020) examine the challenges associated with strategic planning and the difficulties institutions encounter in integrating enterprise systems like SAP into business school curricula. In the context of these developments, Heim et al. (2024) investigate implementing technology-mediated learning (TML) strategies to enhance enterprise software training.

Students must gain practical, hands-on experience to learn about complex systems such as SAP XSUAA effectively. Studies that advocate the "learning by doing" approach with ERP systems demonstrate a notable increase in student competency and satisfaction (Chimgee et al., 2020; Susanti et al., 2020). Holmes et al. (1999) were among the first to address the challenges of integrating SAP R/3 into management information systems and business curricula. They suggested that web-based courses could increase accessibility and engagement (Mesicek, 2018; Orosz, 2020). Winney et al. (2011) discuss the necessity for curriculum innovation, reflecting on the technological changes and the integration of SAP ERP to meet these changes. This is further reinforced by the standardized training needs identified by the SAP University Alliance program (Khoury et al., 2015), which are paramount for ensuring faculty and institutional readiness.

Holmes et al. (1999) and Seto and Ahmed (2008) have provided insights into the frameworks and challenges associated with integrating SAP R/3 and specialized management information systems into curricula. They have emphasized the importance of connecting theoretical knowledge with practical business processes. These insights inform the integration of SAP XSUAA into FH Aachen's cybersecurity curriculum, ensuring its alignment with industry requirements and enhancement of employability (Iriberri et al., 2014). This comprehensive strategy aligns with the objectives of this paper, addressing research questions concerning

[3] https://datatracker.ietf.org/doc/html/rfc6749
[4] https://openid.net/

curriculum effectiveness and industry alignment and anticipates the needs of professional environments in cybersecurity education.

4. Integrating SAP Security Technology into Cybersecurity Curriculum

The increasing complexity of cyber threats requires incorporating advanced security technologies into educational curricula. This case study from FH Aachen outlines a structured methodology for integrating SAP's XSUAA security technology into the cybersecurity curriculum for the Bachelor of Computer Science. This model benefits universities seeking to enrich cybersecurity education with practical, hands-on training using cutting-edge technologies.

Fig 1 shows a five-step approach to integrating XSUAA into the cybersecurity curriculum. This approach provides a comprehensive learning experience that covers theoretical foundations and practical applications.

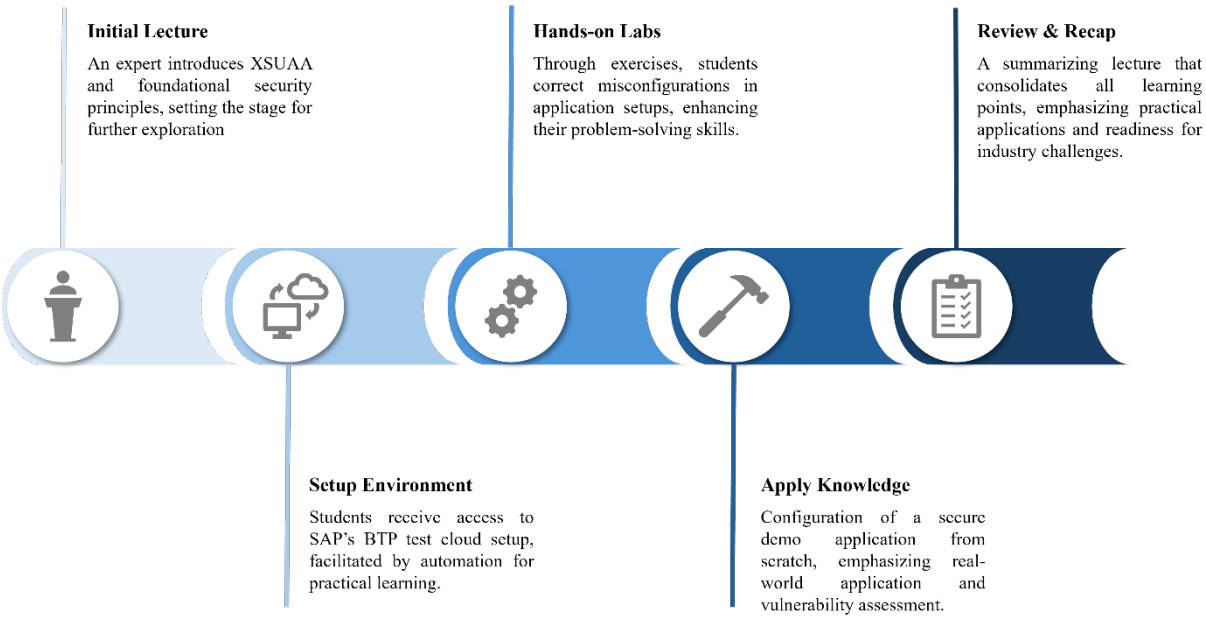

Fig. 1: Five-Step Integration of SAP Security Technology into the Cybersecurity Curriculum

The first step of the curriculum begins with an introductory lecture delivered by an SAP security expert. This session is designed to introduce students to the SAP world, focusing on SAP's XSUAA service for managing secure access to applications. The lecture covers fundamental concepts and the importance of robust authentication and authorization mechanisms in securing applications. In the second step, each student must set up his or her training environment on SAP BTP. Each student must register for an SAP BTP trial cloud environment to do this. This will be their training environment, and they will later deploy various training applications in the lab to deepen the concept of SAP XSUAA.

The third step is a hands-on lab. Students will participate in two targeted labs designed to deepen their understanding of authentication, authorization, and SAP BTP technology, including XSUAA. In the hands-on lab, students must first complete the Build a Business Application Using CAP for Java tutorial to familiarize themselves with the SAP BTP environment and understand how cloud application deployment works in an industry context. These exercises involve working with intentionally misconfigured XSUAA configurations in

their training environments that students must diagnose and correct to create a secure, production-ready application. This level reinforces the theoretical concepts discussed and enhances problem-solving skills in a real-world context.

In the advanced phase, the fourth step, students undertake a project to configure a secure demo application from scratch using XSUAA. Throughout this process, they apply their accumulated knowledge under the guidance of the SAP security expert. This phase is critical because it introduces students to potential real-world attacks by demonstrating vulnerabilities during the configuration phase. A series of relevant exploits at the beginning of this phase are introduced and then progressively mitigated as students apply secure configurations.

The fifth and final phase includes a wrap-up lecture by the SAP security expert summarizing the entire learning experience. This session aims to consolidate the knowledge and skills acquired, emphasizing the practical applications and challenges faced during the module.

5. Evaluation

This section evaluates the effectiveness of integrating SAP XSUAA into the Cybersecurity curriculum based on quantitative and qualitative data collected from a survey of Cybersecurity program students.

5.1. Quantitative Findings

The survey received responses from 20 of 41 cybersecurity students (49% response rate) from two degree programs (Cybersecurity Management and Cybersecurity). It used Likert scales and open-ended questions to assess students' interest in and perceived relevance of SAP security technologies to their professional development.

Interest Level: The average student interest level in learning about SAP XSUAA was 3.8 out of 5. This indicates a moderate level of enthusiasm, suggesting that while students are generally optimistic about learning about SAP technologies, there is potential to increase this interest through improved curriculum connections to real-world applications.

Career Relevance: Students rated the relevance of SAP security technologies to their future careers at an average of 3.65 out of 5. While this indicates an awareness of the importance of security technologies, it also suggests a need to demonstrate how these skills translate into career opportunities more clearly.

Understanding of Core Concepts: The average rating for students' understanding of identity and access management was 2.47 out of 5, indicating significant room for improvement in the foundational knowledge critical to understanding more advanced security concepts.

5.2. Qualitative Findings

Feedback from open-ended questions provided more profound insights into students' experiences and perceptions:

Hands-on Engagement: A recurring theme in the feedback was the desire for more hands-on experience. Students highlighted the value of hands-on labs and real-world scenarios to improve their understanding and retention of SAP security concepts.

Accessibility of resources: Students reported challenges accessing necessary learning materials and SAP environments, suggesting a need for greater resource availability, which could be addressed through enhanced partnerships or subscriptions with SAP.

Expert guidance: Positive feedback was received regarding the involvement of SAP security experts, but students expressed a desire for more frequent and in-depth interactions to support their learning and problem-solving during labs and projects.

6. Enhancing Cybersecurity Education with SAP XSUAA at FH Aachen

Integrating SAP XSUAA into the cybersecurity curriculum at FH Aachen represents a proactive approach to bridging the gap between academic education and industry requirements. The data from the student surveys reflect a moderate to high level of interest and perceived relevance, signaling a positive reception to incorporating real-world tools and methods into the educational framework. However, the evaluation also highlighted the need for improved foundational knowledge and more hands-on experience to realize the full benefits of this integration.

The moderate enthusiasm for SAP XSUAA and its application in securing digital assets illustrates a critical point. While students recognize the importance of such technologies, the direct link to their career advancement and practical implementation details could be made more explicit. This could be done, e.g., by using SAP products during studies like the proposed integration of the SAP BTP trial cloud environment and SAP XSUAA within the cybersecurity curriculum, which increases the visibility and importance of SAP products for all students. Improvements in curriculum design to include more practical, real-world scenarios and deeper engagement with industry experts could increase student interest and practical competence.

6.1. Conclusion

This study confirms that integrating sophisticated, real-world technologies such as SAP XSUAA into cybersecurity curricula can significantly enhance such programs' educational value and relevance. By equipping students with skills directly applicable in the workplace, the curriculum better prepares them for immediate employment. It reduces onboarding time and training costs for potential employers, benefiting the broader cybersecurity landscape.

In addition, the curriculum developed at FH Aachen successfully addresses several critical educational objectives, such as understanding advanced security mechanisms and diagnosing complex cloud environments, which are essential in today's connectivity-driven world.

6.2. Outlook

As FH Aachen incorporates state-of-the-art technologies such as SAP XSUAA into its cybersecurity curriculum, assessing their practical applicability and efficacy is imperative. The curriculum must also be continuously adapted by incorporating feedback from students and industry stakeholders to ensure its continued relevance and impact.

An increased emphasis on hands-on engagement in laboratory settings and project-based work will enable students to confront authentic challenges and evaluate their preparedness for the professional realm. Establishing collaborative relationships with prominent industry partners, such as SAP, will facilitate access to the most recent tools and educational resources, thereby ensuring the currency of the curriculum. Furthermore, fostering connections with industry

professionals through workshops and guest lectures will facilitate adaptation to the latest industry challenges and innovations.

Future research could concentrate on the long-term impact of SAP XSUAA training on graduates' career trajectories and performance in professional settings. A comparative analysis of instructional methods for teaching complex systems like SAP could provide evidence-based recommendations for curriculum design. Furthermore, investigating the scalability of SAP XSUAA integration in diverse educational contexts and analyzing continuous professional development for educators could yield valuable insights.

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Fachspezifische und individuelle Lernpfade in der SAP-Ausbildung

S. Wolf, M. Trommer, T. Teich, T. Neumann
Westsächsische Hochschule Zwickau, Zwickau, Deutschland

Abstract: Der Einstieg in SAP kann aufgrund der Komplexität der Software eine große Herausforderung darstellen, die eine steile Lernkurve erfordert. Insbesondere Neueinsteiger ohne Vorkenntnisse haben Schwierigkeiten, sich zurechtzufinden. Schulungen sind unerlässlich, um die komplexen Funktionen und die Bedienung von SAP zu erlernen. Um Überforderung zu vermeiden und unterschiedliche Vorkenntnisse zu berücksichtigen, müssen die Lernpfade angepasst werden. Ein Problem ist, dass Schulungsunterlagen oft starr sind und keinen direkten Bezug zum Arbeits- oder Studienumfeld der Teilnehmer herstellen. LaTeX bietet gegenüber herkömmlichen Textverarbeitungsprogrammen erhebliche Vorteile bei der Erstellung und Verwaltung komplexer Dokumente. Die Unterstützung von Makros und Paketen in LaTeX erweitert die Funktionalität und ermöglicht eine fachspezifische Anpassung der Lerninhalte, um den Lernprozess der Teilnehmer weiter zu unterstützen. Ergänzt durch Skripte können LaTeX-Dokumente schnell an den gewünschten Lernweg angepasst werden.

Keywords: SAP, fachspezifische und individualisiertes Lernpfade, LaTeX, Learning Analytics

1. Einleitung

SAP stellt für die meisten Erstanwender aufgrund der Komplexität der Software eine Herausforderung dar. SAP ist eine sehr umfangreiche Unternehmenssoftware mit vielen Modulen und Funktionen, deren Umfang und Tiefe überwältigend sein kann. Dies führt zu einer steilen Lernkurve, die insbesondere für Neueinsteiger ohne Vorkenntnisse in Unternehmenssoftware schwer zu bewältigen ist. Des Weiteren erfordert SAP häufig ein gewisses technisches Grundverständnis, insbesondere im Hinblick auf die Integration mit anderen Systemen, das Customizing sowie die Abhängigkeiten der einzelnen Module. Ein weiterer Aspekt, der den Einstieg erschwert, ist die komplexe Benutzeroberfläche von SAP, die nicht sehr intuitiv gestaltet ist. Neue Anwender müssen sich an die spezielle Navigation und die verschiedenen Transaktionscodes gewöhnen, was einen zusätzlichen Lernaufwand bedeutet. Die genannten Faktoren machen den Einstieg in SAP zu einer anspruchsvollen Aufgabe.

Um die komplexen Funktionen und die Bedienung der Software zu erlernen, sind Schulungen unerlässlich. Dabei beginnen nicht alle Schulungsteilnehmer mit den gleichen Voraussetzungen bei der Aufnahme und Umsetzung des vermittelten Wissens (Gabryelski 2022). Um einer Überforderung der Teilnehmer vorzubeugen und den unterschiedlichen Erfahrungen und technischen Vorkenntnissen gerecht zu werden, kann eine Anpassung der Komplexität mittels Lernpfade hilfreich sein. Allerdings zeigt sich in der Praxis, dass die Schulungsunterlagen oft sehr starr gestaltet sind und keinen direkten thematischen Bezug zum Arbeits- oder Studienumfeld der Schulungsteilnehmer herstellen. Ein Beispiel für eine wenig zielführende Gestaltung ist die eintägige SAP-Einführungsschulung der Westsächsischen Hochschule Zwickau, die anhand eines „Schaltwellenmodells" durchgeführt wird. Dieses Modell ist für eine Lehrveranstaltung an einer Fakultät für Pflege- und Gesundheitswissenschaften wenig relevant. Es ist zu eruieren, auf welche Weise die Schulungsunterlagen für die Teilnehmer entsprechend

ihrer Studienrichtung, deren Fähigkeiten sowie den Vorerfahrungen individualisiert werden können, um den Lernprozess effektiver und relevanter zu gestalten.

2. Lehrunterlagen

Der Einsatz von Learning Analytics zur Verbesserung der SAP-Ausbildung an der WHZ ermöglicht die Erfassung und Analyse von Lernfortschritten (Trommer 2023). Das Ziel ist die Anpassung der Kursinhalte an das Niveau der Teilnehmer. Dazu müssen entsprechende Entscheidungspunkte auf dem Lernweg der Teilnehmer vorhanden sein, die eine Anpassung des Schwierigkeitsgrades nach oben, unten und konstant ermöglichen. Dies bedingt einen initialen Aufwand, in dessen Rahmen in den Trainingseinheiten im SAP-System alternative Versionen, Ergänzungen, Hinweise, Zusatzaufgaben etc. einzufügen sind. Ausgehend von der Schritt-für-Schritt-Klickanleitung im SAP-System sind folgende Anpassungen zur Erhöhung des Schwierigkeitsgrades möglich:

- Anzahl der anzulegenden Stammdaten bzw. der durchzuführenden Transaktionen erhöhen.
- Wiederholung der Transaktion ist keine Schritt-für-Schritt-Klickanleitung.
- Nach dem obligatorischen Teil werden zusätzliche Aufgaben angeboten, die die Transaktion wiederholen und kleine Abweichungen von der vorherigen Transaktion aufweisen.
- Schritt-für-Schritt-Klickanleitungen werden durch eine Szenariobeschreibung mit Hinweisen ersetzt, bei der die Durchführung selbst erarbeitet werden muss.

Der Teilnehmer durchläuft entsprechend der Analysen des Lernfortschritts einen individuellen Lernpfad, der an den Entscheidungspunkten iterativ angepasst wird. Siehe hierzu die Abb. 1.

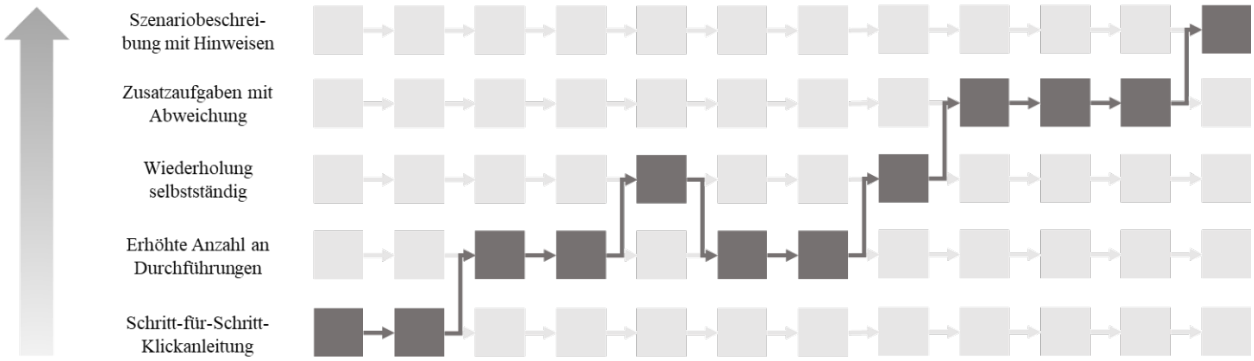

Abb. 1: Individuelle Lernpfad (Roegner 2021)

Die fachspezifischen und individuellen Lernpfade bieten ebenso Vorteile für die Trainer. Die Trainer können durch die unterschiedlichen Schwierigkeitsgrade der Trainingsunterlagen gezielt auf die Bedürfnisse der Teilnehmer eingehen. Bei schwächeren Teilnehmern kann der Trainer eine intensivere Betreuung anbieten, während stärkeren Teilnehmern mehr Freiraum gelassen wird, die Trainingsziele zu erreichen.

Die Lehrunterlagen umfassen in der Regel eine Präsentation mit BWL- und SAP-Theorie, Übungsaufgaben sowie eine Anleitung für die SAP-Anwendungen (Teich 2020), die mit LaTeX erstellt werden.

3. LaTeX

LaTeX ist ein Textsatzsystem, das sich insbesondere für die Erstellung wissenschaftlicher und technischer Dokumente eignet. Es basiert auf TeX, einem Textsatzsystem, das von Donald Knuth in den späten 1970er Jahren entwickelt wurde. LaTeX erweitert TeX um Makros und bietet eine Reihe von vordefinierten Befehlen und Strukturen, die das Schreiben und Formatieren komplexer Dokumente erleichtern und beschleunigen. Siehe hierzu Abb. 2.

```
Sie beginnen mit dem Anlegen der \emph{Fertigerzeugnisse}:

\begin{itemize}
  \item Schaltwelle WM-1001-\#\#
  \item Gehäuse-komplett  WM-1101-\#\#
\end{itemize}

Zum Anlegen der Schaltwelle verfahren Sie wie folgt:

\textbf{GUI-Menüpfad:} $\rightarrow$ Logistik $\rightarrow$ Materialwirtschaft $\rightarrow$ Materialstamm
$\rightarrow$ Material $\rightarrow$ Anlegen allgemein $\rightarrow$ Sofort
```

Abb. 2: Textsatzsystem von LaTeX

Ein wesentliches Merkmal von LaTeX ist die präzise Formatierung, die das Textsatzsystem insbesondere für wissenschaftliche Arbeiten, Bücher, Artikel und technische Dokumentationen prädestiniert. Durch eine Vielzahl an Paketen und Erweiterungen kann LaTeX an die spezifischen Bedürfnisse eines Projekts angepasst werden. Diese Pakete decken eine Vielzahl von Funktionen ab, von Grafiken und Tabellen bis hin zu speziellen Layouts und Schriften.

LaTeX zeichnet sich durch eine klare Trennung von Textinhalt und Layout aus. Dadurch wird den Autoren die Möglichkeit eröffnet, sich auf das Schreiben zu konzentrieren, während LaTeX sich um das Aussehen des Dokuments kümmert. LaTeX wird in einer einfachen Textdatei geschrieben und dann kompiliert, um das fertige Dokument zu erzeugen, meist im PDF-Format. Es findet insbesondere in akademischen Kreisen sowie in Branchen, die präzise und strukturierte Dokumentationen erfordern, Anwendung.

3.1. Vorteile von LaTeX zu Textverarbeitungsprogrammen

Im Vergleich zu herkömmlichen Textverarbeitungsprogrammen wie Microsoft Word bietet LaTeX erhebliche Vorteile bei der Erstellung und Verwaltung komplexer Dokumente. Zu den wichtigsten Vorteilen zählen:

- **Modularität und Strukturierung:** TeX ermöglicht die Unterteilung großer Dokumente in mehrere Dateien, die später zusammengefügt werden können. Dies erleichtert die Verwaltung und Bearbeitung einzelner Abschnitte, Kapitel oder Anhänge.
- **Automatische Inhaltsverzeichnisse, Abbildungs- und Tabellenverzeichnisse:** LaTeX erstellt automatisch Inhaltsverzeichnisse, Abbildungsverzeichnisse und Tabellenverzeichnisse, die sich bei Änderungen im Dokument automatisch aktualisieren.
- **Referenzierung und Verlinkung:** LaTeX bietet leistungsstarke Mechanismen zur Querverweis- und Zitatverwaltung. Interne Referenzen (z. B. zu Kapiteln, Abbildungen, Tabellen) und externe Literaturverweise werden automatisch nummeriert und aktualisiert.

- **Konsistente Formatierung:** LaTeX gewährleistet eine konsistente Formatierung im gesamten Dokument. Stilvorgaben für Überschriften, Absätze, Zitate, Listen und andere Elemente werden zentral definiert und einheitlich angewendet.
- **Umgang mit großen Datenmengen:** LaTeX kann effizient mit großen Datenmengen umgehen, sei es Text, Tabellen oder Abbildungen. Es bleibt stabil und performant, auch wenn das Dokument sehr umfangreich wird.
- **Makros und Pakete:** LaTeX unterstützt die Verwendung von Makros und Paketen, welche die Funktionalität erweitern und wiederkehrende Aufgaben automatisieren. Dies führt zu einer Zeitersparnis und einer Reduktion von Fehlern.
- **Zusammenarbeit und Versionskontrolle:** Die Zusammenarbeit und Versionskontrolle werden durch die einfache Textdatei-Struktur von LaTeX-Dokumenten ebenfalls erleichtert. Dies ermöglicht das gemeinsame Arbeiten an großen Projekten und das Nachverfolgen von Änderungen.

3.2. Anpassung der Lehrunterlagen mittels LaTeX-Funktionalitäten

Insbesondere die Punkte Modularität und Strukturierung, der Umgang mit großen Datenmengen sowie die Verwendung von Makros und Paketen sind für die Umsetzung der verschiedenen Lernpfade und individualisierten Lernmaterialien von großer Bedeutung.

Strukturierung

Die Struktur kann u.a. mit Hilfe verschiedener Dateien realisiert werden, die dann über LaTeX-Befehle in das Hauptdokument eingefügt werden können. Beispielsweise könnten die Stammdaten für logistische Prozesse wie Materialien, Stücklisten, Arbeitspläne und Fertigungsversionen in einzelnen tex-Dateien abgebildet werden. Diese Dateien werden dann in einem Hauptdokument zusammengefasst, wodurch eine übersichtliche und geordnete Darstellung der Inhalte ermöglicht wird. Siehe hierzu Abb. 3.

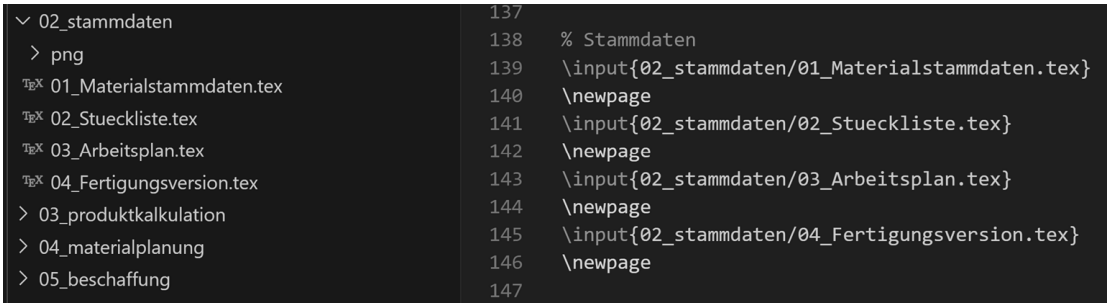

Abb. 3: Strukturierung in LaTeX-Dokumenten

Makro newcommand

Makros sind hilfreiche Funktionen von LaTeX, mit deren Hilfe neue Befehle hinzugefügt werden können. Diese können verwendet werden, um Platzhalter im Dokument erstellen. Der Befehl hierfür ist „\newcommand{\Befehl}{Einfügetext}“. Die Abb. 4 zeigt das LaTeX-Dokument mit den neuen Befehlen für die Schaltwelle, die ins Hauptdokument integriert wird.

```latex
% Alltemeine Platzhalter
\newcommand{\ku}{$\#\#$ } % Kürzel \ku --> ##
\newcommand{\fs}{Schaltwelle_neu} % Fallstudienbezeichnung \fs --> Schaltwelle

%%%% Materialstamm %%%%

% Material 0
\newcommand{\matnullbez}{Schaltwelle } % Bezeichnung Material 0: \matnullbez --> Schaltwelle
\newcommand{\matnullnr}{WM-1001-} % Nummer Material 0: \matnullnr --> WM-1001-
\newcommand{\matnullma}{Fertigerzeugnis } % Materialart Material 0: \matnullma --> Fertigerzeugnis

% Material 1
\newcommand{\mateinsbez}{Gehäuse-komplett } % Bezeichnung Material 1: \mateinsbez --> Gehäuse-komplett
\newcommand{\mateinsnr}{WM-1101-} % Nummer Material 1: \mateinsnr --> WM-1101-
\newcommand{\mateinsma}{Fertigerzeugnis } % Materialart Material 1: \mateinsma --> Fertigerzeugnis
```

Abb. 4: LaTeX-Makro - newcommand

Diese Befehle können für die Klickanleitung verwendet werden und ersetzen den ursprünglichen Text. Die Abb. 5 zeigt in Anlehnung an den Ausschnitt aus Abb. 2 die Verwendung der neuen Befehle in der Klickanleitung und den Ausschnitt aus der erzeugten PDF.

```latex
Sie beginnen mit dem Anlegen der Materialien mit der Materialart \emph{\matnullma}:

\begin{itemize}
  \item \matnullbez \matnullnr\ku
  \item \mateinsbez \mateinsnr\ku
\end{itemize}

Zum Anlegen der \matnullbez verfahren Sie wie folgt:

\textbf{GUI-Menüpfad:} $\rightarrow$ Logistik $\rightarrow$ Materialwirtschaft $\rightarrow$ Materialstamm
$\rightarrow$ Material $\rightarrow$ Anlegen allgemein $\rightarrow$ Sofort
```

Sie beginnen mit dem Anlegen der Materialien mit der Materialart *Fertigerzeugnis* :

- Schaltwelle WM-1001-##
- Gehäuse-komplett WM-1101-##

Zum Anlegen der Schaltwelle verfahren Sie wie folgt:

GUI-Menüpfad: → Logistik → Materialwirtschaft → Materialstamm → Material → Anlegen allgemein → Sofort

Abb. 5: Verwendung der neuen Makro-Befehle und der dazugehörigen PDF-Darstellung.

In einer weiteren Datei könnten die neuen Befehle mit anderen Werten gefüllt werden, die dann spezifischer auf andere Fachbereiche zugeschnitten sind. Beispielsweise könnte die bisherige Klickfallstudie mit der „Schaltwelle“ durch ein anderes fachspezifisches Produkt ersetzt werden. Für die Fakultät Gesundheits- und Pflegewissenschaften könnte das Fertigerzeugnis durch eine Dienstleistung, wie einen „ambulanten Pflegebesuch“, ersetzt werden. In diesem Kontext wäre es beispielsweise denkbar, eine weitere Dienstleistung „Anfahrt“, sowie ein Fertigerzeugnis „Behandlerset“, bestehend aus „Handschuhen“, „Desinfektionsmittel“ und „Schutzkleidung“, in die Stückliste aufzunehmen. Die Abb. 6 zeigt eine angepasste LaTeX-Datei mit dem dazugehörigen PDF-Auszug. Eine Anpassung der Hauptdatei ist nicht erforderlich, da diese auf die Platzhalterbefehle zurückgreift.

```
% Alltemeine Platzhalter
\newcommand{\ku}{$\#\#$ } % Kürzel \ku --> ##
\newcommand{\fs}{ambulante Pflege} % Fallstudienbezeichnung \fs --> ambulante Pfl

%%%% Materialstamm %%%%

% Material 0
\newcommand{\matnullbez}{ambulanter Pflegebesuch } % Bezeichnung Material 0: \mat
\newcommand{\matnullnr}{AP-1001-} % Nummer Material 0: \matnullnr --> AP-1001-
\newcommand{\matnullma}{Dienstleistung } % Materialart Material 0: \matnullma -->

% Material 1
\newcommand{\mateinsbez}{Anfahrt } % Bezeichnung Material 1: \mateinsbez --> Anfa
\newcommand{\mateinsnr}{AP-1101-} % Nummer Material 1: \mateinsnr --> AP-1101-
\newcommand{\mateinsma}{Dienstleistung } % Materialart Material 1: \mateinsma -->
```

Sie beginnen mit dem Anlegen der Materialien mit der Materialart *Dienstleistung* :

- ambulanter Pflegebesuch AP-1001-##
- Anfahrt AP-1101-##

Zum Anlegen der ambulanter Pflegebesuch verfahren Sie wie folgt:

GUI-Menüpfad: → Logistik → Materialwirtschaft → Materialstamm → Material → Anlegen allgemein → Sofort

Abb. 6: Makro-Befehle mit neuen Inhalten und der dazugehörigen PDF-Darstellung

Kommentarfunktion und Makro in-/exclude

Die Ausblendung von Dateien und Bereichen kann im Latex-Format auf zwei verschiedene Arten erfolgen. Die erste Möglichkeit ist das Auskommentieren mittels des %-Zeichens, welches insbesondere für kurze Textpassagen und einzelne Zeilen geeignet ist. Die Abb. 7 zeigt das Auskommentieren der verschiedenen Dateien für die unterschiedlichen Fachbereiche.

```
% Neue Befehle
%\input{fallstudien_schaltwelle.tex}
\input{fallstudien_pflege_dienstleistung.tex}
```

Abb. 7: Ein-/Ausbleden mittels Kommentarfunktion in LaTeX

Als zweite Möglichkeit kann für das Ein- beziehungsweise Ausblenden von Textinhalten das Makro „\excludeversion{Bezeichnung}“ bzw. „\includeversion{Bezeichnung}“ angeführt werden. Dabei wird eine Bezeichnung definiert, die bei der Verwendung des Makros excludeversion ausgeblendet und bei der Verwendung des Makros includeversion eingeblendet wird. Im Text muss der ein- bzw. auszublendende Text innerhalb der Befehle „\begin{Bezeichnung} … \end{Bezeichnung}“ platziert werden. Die Abb. 8 demonstriert ein Beispiel für das Klickdokument der Trainingsfallstudie mit unterschiedlicher Inhaltsmenge. Die linke Seite zeigt den reduzierten Inhalt, bei dem unter anderem lediglich vier Materialien, eine Stückliste sowie ein Arbeitsplan angelegt werden. Demgegenüber werden auf der rechten Seite (verkürzt Darstellung) acht Materialien, zwei Stücklisten und vier Arbeitspläne angelegt.

```
47  \includeversion{E1} % Schaltwelle einstufiger Stückliste
48  \excludeversion{E2} % Schaltwelle zweistufiger Stückliste
```

```
16  \begin{E1}
17
18  \begin{center}
19  \begin{tabular}{|l|l|}
20      \hline
21      Material & Materialart \\
22      \hline
23      \matnullbez \matnullnr\ku & \matnullma \\
24      \hline
25      \mateinsbez \mateinsnr\ku & \mateinsma \\
26      \hline
27      \matzweibez \matzweinr\ku & \matzweima \\
28      \hline
29      \matdreibez \matdreinr\ku & \matdreima \\
30      \hline
31  \end{tabular}
32  \end{center}
33
34  \end{E1}
```

```
47  \excludeversion{E1} % Schaltwelle einstufiger Stückliste
48  \includeversion{E2} % Schaltwelle zweistufiger Stückliste
```

```
36  \begin{E2}
37
38  \begin{center}
39  \begin{tabular}{|l|l|}
40      \hline
41      Material & Materialart \\
42      \hline
43      \matnullbez \matnullnr\ku & \matnullma \\
44      \hline
```

```
53      \matfuenfbez \matfuenfnr\ku & \matfuenfma \\
54      \hline
55      \matsechsbez \matsechsnr\ku & \matsechsma \\
56      \hline
57      \matsiebenbez \matsiebennr\ku & \matsiebenma \\
58      \hline
59  \end{tabular}
60  \end{center}
61
62  \end{E2}
```

Abb. 8: Verwendung von LaTeX-Makro in-/exclude

In Abhängigkeit von den Fähigkeiten und den Vorerfahrungen der einzelnen Teilnehmer kann der Umfang und die Schwierigkeit der Inhalte angepasst werden. Dadurch wird gewährleistet, dass sowohl die schnelleren als auch die langsameren Kursteilnehmer angemessen gefordert und gefördert werden. Die schnelleren Kursteilnehmer erhalten mehr Inhalte und die Wartezeiten reduzieren sich, während die langsameren Kursteilnehmer durch den geringeren Umfang nicht abgeschreckt und demotiviert werden.

3.3. LaTeX-Workshop

LaTeX ist ein weit verbreitetes Textsatzsystem, das sich insbesondere für die Erstellung wissenschaftlicher und technischer Dokumente eignet. *LaTeX Workshop* (LaTeX Workshop 2024) stellt eine Erweiterung für den weit verbreiteten Code-Editor Visual Studio Code (VSC) dar, welche die Erstellung, Bearbeitung und Kompilierung von LaTeX-Dokumenten unterstützt. Die Erweiterung bietet eine Vielzahl von Funktionen, die speziell auf die Bedürfnisse von LaTeX-Nutzern zugeschnitten sind. Die Nutzung von LaTeX Workshop in VSC bietet insbesondere den Vorteil, weitere Programmiersprachen einsetzen zu können. So können beispielsweise mit Hilfe der Programmiersprache Python-Skripte geschrieben werden, die automatisch Anpassungen in den LaTeX-Dateien vornehmen. Die Abb. 9 demonstriert die Funktionsweise eines Python-Skripts, welches ein Array von tex-Dateien nutzt, um die Bezeichnung „Schaltwelle“ durch den neuen Befehl „\matnullbez“ zu ersetzen. Letzterer wurde mithilfe des LaTeX-Makros „\newcommand“ erstellt.

```python
# Schleife, die jede Datei in der Liste bearbeitet
for dateiname in dateien:
    input_file_path = os.path.join(basispfad, dateiname)  # Vollständiger Pfad zur Eingabedatei
    output_file_path = os.path.join(basispfad, dateiname.replace('.tex', '_neu.tex'))  # Vollständiger Pfad zur Ausgabedatei

    # Datei lesen
    with open(input_file_path, 'r', encoding='utf-8') as file:
        content = file.read()

    # Inhalt bearbeiten
    modified_content = content.replace('Schaltwelle', '\matnullbez')

    # Geänderten Inhalt in neuer Datei speichern
    with open(output_file_path, 'w', encoding='utf-8') as file:
        file.write(modified_content)

    print(f"Datei {dateiname} erfolgreich geändert und gespeichert als '{output_file_path}'.")
```

Abb. 9: Nutzung von Skripten zur Anpassung von LaTeX-Dokumenten

4. Zusammenfassung und Ausblick

Der Einsatz von Learning Analytics zielt auf die Anpassung der Kursinhalte an das Niveau der Teilnehmer ab. Dazu müssen Entscheidungspunkte auf dem Lernpfad definiert werden, die beispielsweise eine Anpassung der Lehrunterlagen ermöglichen. Hierfür können LaTeX-Makros „\newcommand“ und „\include“ bzw. „\exclude“ sowie automatisierte Skripte zur Individualisierung eingesetzt werden. Die Anpassungen umfassen die Erhöhung der anzulegenden Stammdaten, Szenariobeschreibungen anstelle von Schritt-für-Schritt-Anleitungen sowie Zusatzaufgaben. Gleichzeitig können die Trainingsinhalte für die Teilnehmer fachspezifisch gestaltet werden, wodurch die Wissensvermittlung noch gesteigert werden kann.

Die Westsächsische Hochschule Zwickau plant eine Ausweitung der individuellen und fachspezifischen Lernpfade auf weitere SAP-Kurse. Ziel ist es, eine noch stärkere Automatisierung bei der Erstellung von Lehrunterlagen zu erreichen. Zu diesem Zweck sollen Large Language Models (LLMs) eingesetzt werden, die eine fachspezifische Anpassung der Lehrunterlagen in kurzer Zeit vornehmen können. Des Weiteren ist das Training eigener LLMs im Bereich Learning Analytics vorgesehen, welche an den Entscheidungspunkten eine Anpassung der Lernpfade vornehmen kann. Darüber hinaus sollen LLMs als Chatfunktion für die Kursteilnehmer dienen, um bei konkreten Problemen zu den Kursinhalten helfen können.

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Berufliche Handlungskompetenz gut erzählt – Vorstellung und Wirksamkeit verschiedener Ansätze zur Einführung in SAP S/4HANA mit Hilfe von Storytelling

Anja Rogas[1], Marko Ott[2] & Robert Häusler[3]
[1] Professur für Wirtschaftspädagogik/Professur für Wirtschaftsinformatik, insb. ISIH, Fakultät Wirtschaftswissenschaften, TU Dresden, Deutschland
[2] Informatiklabor, Fakultät Wirtschaftswissenschaften, TU Dresden, Deutschland
[3] MRCC & SAP UCC Magdeburg, Fakultät für Informatik, Otto-von-Guericke-Universität Magdeburg, Deutschland

Abstract: Der vorliegende Beitrag macht deutlich, dass (digitales) Storytelling eine adäquate Lehr-Lernmethode darstellt, um Lernende bei der Entwicklung beruflicher Handlungskompetenz zu unterstützen. Am Beispiel der Einführung in SAP S/4HANA werden drei Ansätze vorgestellt, die insbesondere die Entwicklung digitaler Grundfähigkeiten fördern können. Es handelt sich dabei um eine (1) textbasierte und (2) Graphic Novel-basierte Überarbeitung der von den SAP University Competence Centern bereitgestellten Fallstudien sowie der Entwicklung eines (3) onlinebasierten Serious Games, das ergänzend zu den Fallstudien eingesetzt werden kann. Erste Ergebnisse zum Einsatz des textbasierten Storytellings zeigen, dass die von uns theoretisch abgeleiteten Annahmen bezüglich der kognitiven Belastung und der Motivation der Lernenden empirisch nachweisbar sind. Insbesondere hinsichtlich der für das Storytelling relevanten Faktoren germane load und Interesse zeigen sich im Vergleich zum Einsatz der Originalunterlagen signifikante Unterschiede zugunsten des Storytellings. Die Auswertung des Fallstudienmonitors ergab darüber hinaus eine deutliche Reduktion der Abbruchquote sowie der Fehleingaben durch die Lernenden, was auf eine Steigerung der beruflichen Handlungskompetenz schließen lässt.

Keywords: Storytelling, Cognitive Load, Motivation, Graphic Novels, Serious Games

1. Einleitung

1.1. Notwendigkeit des Neudenkens beruflicher Handlungskompetenz

Unternehmen in Industrie und Handel sind geprägt durch ständige technologiegetriebene Weiterentwicklung und eine zunehmende Digitalisierung der Wertschöpfungskette (Klös et al. 2021). Diese fortwährende Digitalisierung führt dazu, dass der Erfolg eines Unternehmens nicht mehr nur von der Leistung einzelner Funktionsbereiche innerhalb der Unternehmung abhängt, sondern viel mehr von der erfolgreichen Integration und Vernetzung funktionsübergreifender Geschäftsprozesse (Große-Schwiep et al. 2020). Dabei werden an die Digitalisierung von Geschäftsprozessen hohe Erwartungen, wie die Steigerung der Effizienz der Unternehmung oder ein qualitativ sowie quantitativ höherer Output, gestellt. Um diesem Anspruch gerecht zu werden, setzen Unternehmen vermehrt Enterprise Resource Planning (ERP) Systeme wie SAP S/4HANA ein.

Die Bedeutung der Digitalisierung sowie der Einsatz von ERP-Systemen bedingen ein Neudenken hinsichtlich der Fähigkeiten, die im Rahmen der Entwicklung beruflicher Handlungskompetenz erworben werden müssen (Geiser et al. 2021). Diese von Kirchherr et al.

(2021) als *digitale Grundfähigkeiten* bezeichneten notwendigen Fähigkeiten, „[…] sich in einer digitalisierten Umwelt zurechtzufinden und aktiv an ihr teilzunehmen“ (S. 5), müssen daher bereits im Studium oder in der Ausbildung erworben werden, um Absolvent:innen bestmöglich auf das bevorstehende Berufsleben vorzubereiten. Das von den SAP University Competence Centern (SAP UCC) angebotene Portfolio zur Einführung in SAP S/4HANA am Beispiel der Modellfirma Global Bike soll zur Entwicklung ebendieser digitalen Grundfähigkeiten beitragen. Es konnte jedoch beobachtet werden, dass es Studierenden schwerfällt, sich selbst zu motivieren und sich kontinuierlich mit den Lerninhalten auseinanderzusetzen.

1.2. Storytelling in der Theorie – Kurzvorstellung des theoretischen Rahmens

Es stellt sich also die Frage, was Lehrpersonen tun können, um die Motivation der Lernenden zu fördern und sie damit bei der Entwicklung ihrer beruflichen Handlungskompetenz zu unterstützen. Um sich dieser Frage anzunähern, ist es zunächst wichtig zu wissen, was sich hinter dem Begriff *Handlungskompetenz* verbirgt. In der Motivationspsychologie wird Kompetenz als Fähigkeit verstanden, in komplexen (Problem-)Situationen selbstorganisiert und kreativ zu handeln (Heyse 2014; White 1959). Handlungskompetenz umfasst neben kognitiven auch soziale, motivationale, volitionale und moralische Fähigkeiten sowie die Bereitschaft, diese in unterschiedlichen Kontexten verantwortungsvoll einzusetzen (Weinert 2014). Folglich spielen vor allem die aus der Persönlichkeit des Individuums resultierende Motivation und Emotion eine entscheidende Rolle bei der Entwicklung von Kompetenzen (Erpenbeck et al. 2017). Mit Hilfe persönlicher Erfahrungen werden Kompetenzen gefestigt und letztendlich über Motivation und Emotion verinnerlicht. Kompetenz und Motivation stehen dabei in Wechselwirkung zueinander. Zum einen ist Motivation grundlegend für die Entwicklung der Handlungskompetenz der Lernenden, zum anderen ist Kompetenzerleben, neben Autonomie und sozialer Verbundenheit, eines der psychologischen Grundbedürfnisse, und als solches entscheidend für die (intrinsische) Motivation der Lernenden (Rogas 2023b).

Für die Entwicklung beruflicher Handlungskompetenz gilt es nun also, Lernumgebungen zu schaffen, in denen die Lernenden in einem beruflichen Kontext selbstorganisiert handeln, indem sie ihre kognitiven, sozialen, motivationalen, volitionalen und moralischen Fähigkeiten einbringen. Selbstorganisation ist dabei nicht gleichzusetzen mit Selbstständigkeit oder Eigeninitiative (Erpenbeck et al. 2017). Vielmehr ist im Sinne eines konstruktivistischen Verständnisses des Lernbegriffs ein individueller Lernprozess anzustoßen, der es den Lernenden ermöglicht, ihr Wissen innerhalb eines bestimmten (beruflichen) Kontextes aktiv selbst zu konstruieren.

Ein Ansatz, diesem Anspruch gerecht zu werden, ist der Einsatz der Lehr-Lernmethode des *Storytellings* (Otto 2020). Bereits 1996 fanden Wissenschaftler des Massachusetts Institute of Technology heraus, dass das Erzählen von Geschichten am besten geeignet ist, um Wissen in einer Unternehmung zu dokumentieren und weiterzugeben (Thier 2006). Das liegt vor allem daran, dass Geschichten es unserem Gehirn erleichtern, neue Informationen mit bereits vorhandenem Wissen zu verknüpfen (Fuchs 2021). Der in Geschichten dargestellte Kontext beschleunigt zudem den Zugriff auf bereits gemachte Erfahrungen. Die Entscheidung darüber, ob eine Information als wichtig oder unwichtig eingestuft wird, wird so zu einem eher unterbewussten kognitiven Prozess und nimmt weniger „Arbeitsspeicher“ des Gehirns in Anspruch. Die Entlastung des Arbeitsgedächtnisses führt gemäß der *Cognitive Load Theory* dazu, dass den Lernenden mehr Kapazitäten für die tatsächliche Informationsverarbeitung, also den Aufbau neuer bzw. die Erweiterung bestehender Wissensstrukturen, zur Verfügung stehen (Sweller 2005). Zudem kann mit Hilfe des Storytellings ein sogenanntes *situationales Interesse*

am Lerngegenstand geweckt und die Lernenden können somit zunächst extrinsisch motiviert werden (Deci & Ryan 1993; Krapp 1992). Wird die Geschichte dann so erzählt, dass die Lernenden positive Erfahrungen bzw. eine positive Erwartungshaltung gegenüber potenziellen Erfahrungen entwickeln, kann dadurch im Idealfall ein *persönliches Interesse* am Lerngegenstand geweckt werden. Die Lernhandlung wäre dann intrinsisch motiviert, was sich letztendlich ebenfalls positiv auf den Prozess der Informationsverarbeitung auswirkt (Rogas 2023b).

Ziel dieses Beitrags ist es, drei auf diesen theoretischen Annahmen basierende Ansätze zur Umsetzung (digitalen) Storytellings vorzustellen. Dabei handelt es sich zum einen um eine iterative Überarbeitung der von den SAP UCCs zur Verfügung gestellten Fallstudien zur Einführung in SAP S/4HANA, in deren Rahmen zunächst eine textbasierte Story implementiert wird, welche im zweiten Schritt in Form einer Graphic Novel (GN) präsentiert wird. Zum anderen handelt es sich um Serious Games, die als Ergänzung der Fallstudien dienen. Als Forschungsmethode zur Evaluation des Outputs aller Ansätze ist der Design-based Research (DBR) Ansatz geeignet.

2. Methodik

2.1. Gestaltung der Interventionen - drei Ansätze des Storytellings

Die ersten beiden Ansätze ergeben sich aus der bereits erwähnten iterativen Überarbeitung der Fallstudien. Die Änderungen erfolgen zunächst beispielhaft für die Fallstudie zur Einführung in SAP S/4HANA in die Materialwirtschaft. In einem ersten Schritt wurden die Fallstudien auf Basis des *Vier-Komponenten-Instruktionsdesigns* (4C/ID) überarbeitet (van Merriënboer 2020). Die Analyse der Lernmaterialien zeigte, dass die vorliegenden Fallstudien die Mehrheit der Merkmale des 4C/ID bereits aufweisen (Ott 2023). Bei der Gestaltung der Kontextauthentizität weisen die Materialien jedoch Schwächen auf. Mit Hilfe des Storytellings soll die Kontextauthentizität erhöht werden. Dafür wird die fallstudienübergreifend wiederkehrende Protagonistin Hilde Haydn eingeführt. Hilde hat gerade ihr wirtschaftlich ausgerichtetes Studium abgeschlossen und wurde im neuen Trainee Programm der Global Bike aufgenommen. Im Zuge dieser Tätigkeit arbeitet sie mit verschiedenen Kolleg:innen unterschiedlicher Funktionseinheiten zusammen, die ihr erklären, wie die jeweiligen Geschäftsprozesse systemisch umgesetzt und miteinander verknüpft sind. Dieser Kontext soll den Lernenden eine potenzielle Erfahrung ihrer zukünftigen beruflichen Lebenswelt aufzeigen und damit das persönliche Interesse wecken. Im zweiten Schritt wird die textbasierte Geschichte in Form von GN dargestellt. Grundlage dafür bilden die von Richard Mayer (2005) begründete *Cognitive Theory of Multimedia Learning* (CTML) und die von Roxana Moreno (2006) weiterentwickelte *Cognitive-Affective Theory of Learning with Media* (CATLM). Neben kognitiven Aspekten identifiziert die CATLM emotionale und motivationale Aspekte als Einflussfaktoren auf die Verarbeitung von Informationen (Rogas 2023a). Abb. 1 stellt die beiden Varianten der überarbeiteten Fallstudie gegenüber.

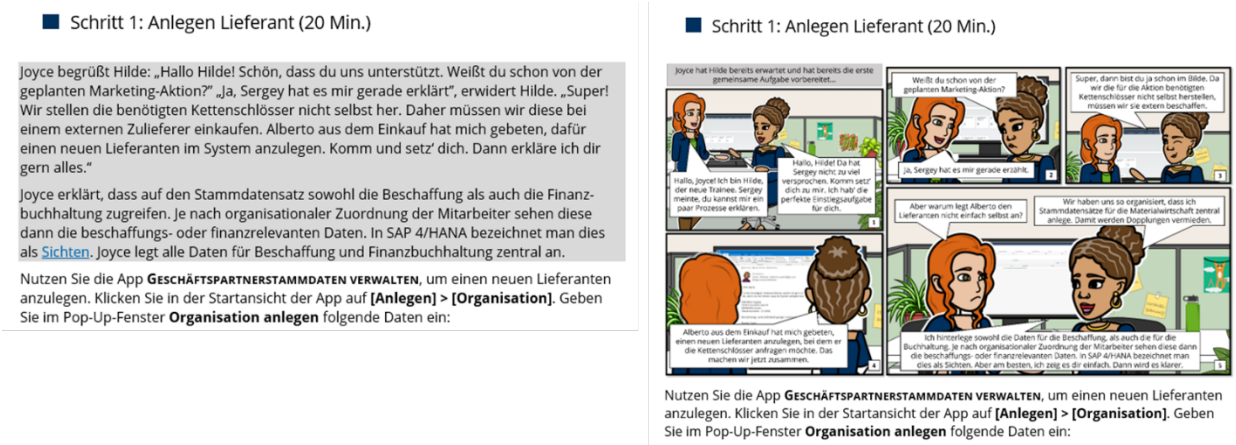

Abb. 1: Gegenüberstellung text- und GN-basierte Überarbeitung der Fallstudie

Ein dritter, davon unabhängiger, Storytelling-Ansatz ist das Einbetten einer Geschichte in ein Spiel. Beim sogenannten *Game-based Learning* steht die spielerische Vermittlung von Wissen im Mittelpunkt (Jacob & Teuteberg 2017). In diese breit gefasste Definition fallen mehrere Konzepte. *Serious Games* sind Spiele, die ihrem Namen nach, ernsthafte Intentionen verfolgen (also über reine Unterhaltung bzw. Entertainment Games hinausgehen) und auf Bildung sowie Problemlösung in verschiedenen Bereichen abzielen. Eine Unterart zur Vertiefung betriebswirtschaftlicher Kompetenzen sind *Business Games* (dt. „Planspiele"). *Gamification* hingegen nutzt lediglich einzelne Spielelemente (Punkte, High Scores, Badges, ...) in sonst spielfremden Kontexten. Die Forschung im Feld der Gamification empfiehlt, Storytelling als Methode einzusetzen, um Inhalte interessanter und ansprechender zu gestalten (Giakalaras 2016). Mit Hilfe dieses Spielelements haben auch Serious Games nicht zuletzt den Anspruch, die Motivation zu erhöhen und den Cognitive Load zu reduzieren (Braad et al. 2016).

Das hier betrachtete Beispiel – *Global Bike Go* – ist eine digitale Mini-Planspiel-Reihe. Aktuell besteht sie aus den drei Spielen „Explore Procurement", „Explore Production" und „Explore Sales", die die Fallstudien zur Einführung in die SAP S/4HANA Module Materialwirtschaft, Produktionsplanung und -steuerung sowie Vertrieb ergänzen sollen (Häusler 2019). Sie behandeln einen Ausschnitt des jeweiligen Geschäftsprozesses und führen gleichzeitig niederschwellig in die neue Fiori-Oberfläche ein. Jedes Spiel wird mit einem ein- bis zweiseitigen Szenario eingeleitet, dessen Story sich an der Modellfirma Global Bike orientiert. Die Planspiele sind dabei als eine vorgelagerte Erweiterung zu den bestehenden Fallstudien zu verstehen, um den Einstieg in das S/4HANA-System (über Fiori) sowie in die betriebswirtschaftliche Thematik zu erleichtern und durch Spielelemente die intrinsische Motivation und das Interesse an den Lerninhalten zu erhöhen (Häusler et al. 2023).

2.2. Evaluation der Fallstudien - Design-based Research als Forschungsmethode

Um nachzuweisen, ob die theoretisch hergeleiteten Effekte tatsächlich auftreten, wird der Einsatz der Fallstudien mit Hilfe des *DBR* Ansatzes (Abb. 2) evaluiert. Dabei handelt es sich um einen in der Bildungsforschung etablierten Forschungsansatz, der es ermöglicht, Theorie und Praxis möglichst eng miteinander zu verzahnen (Barab & Squire 2004; Reinmann 2005). Zunächst erfolgt ein theoriegeleitetes Design einer Intervention. Diese wird wiederholt in natürlichen Lehr-Lernsettings erprobt, evaluiert und ggf. re-designt. In einem iterativen Prozess wird die Intervention somit optimiert und ein Beitrag zur Weiterentwicklung der Ausgangstheorien geleistet.

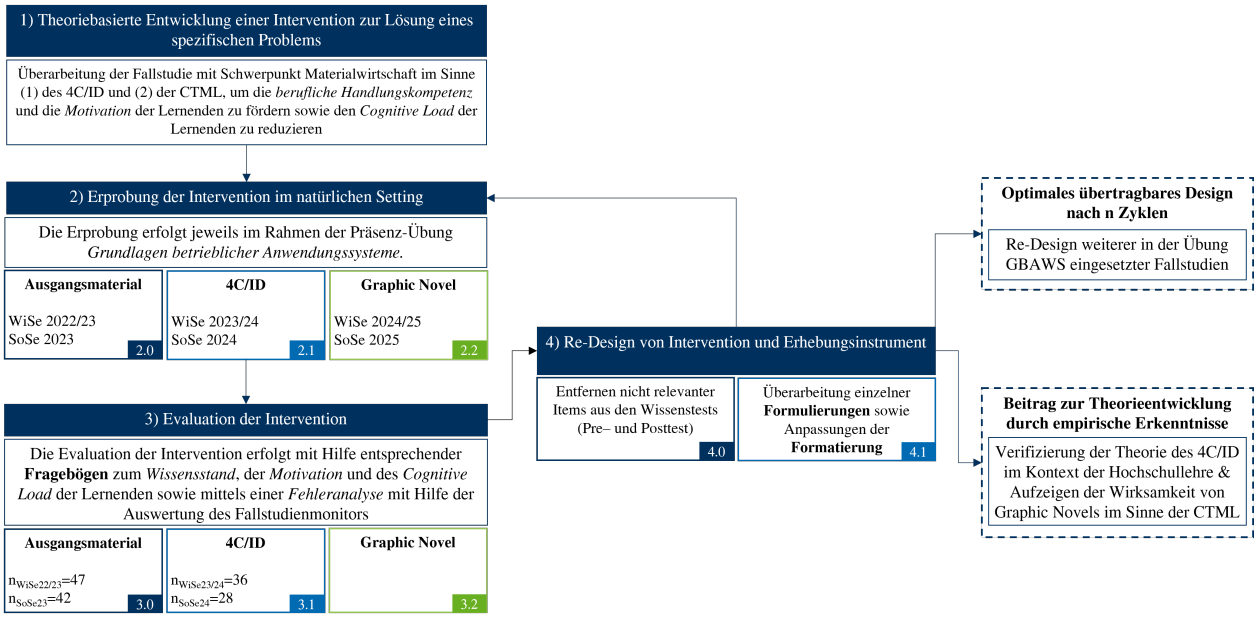

Abb. 2: Umsetzung des DBR Ansatzes (in Anlehnung an Gess et al. 2014)

Evaluiert werden neben der Wissensentwicklung dabei auch der Cognitive Load (CL) und die Motivation der Lernenden. Die Evaluation der Wissensentwicklung erfolgt im Pre-Post-Design mit Hilfe selbst entwickelter Fragebögen. Um die Motivationslage der Lernenden zu beurteilen, füllen diese vor Bearbeitung der Fallstudie eine Adaption des Fragebogens zur Erfassung aktueller Motivation in Lern- und Leistungssituationen (Rheinberg et al. 2001) aus. Nach der Intervention erhalten die Lernenden, neben dem Wissenstest, zusätzlich den Fragebogen zur Messung des CL während der Bearbeitung (Leppink et al. 2013). Die eingesetzten Fragebögen ermöglichen es, die Wirksamkeit der Interventionen hinsichtlich der aus der Theorie hergeleiteten Effekte beurteilen und entsprechende Erkenntnisse ableiten zu können. Zudem wurde der durch das UCC zur Verfügung gestellte Fallstudienmonitor ausgewertet, um typische Fehler zu identifizieren und somit Rückschlüsse auf Unterschiede hinsichtlich der Entwicklung der beruflichen Handlungskompetenz der Lernenden zu ziehen. Einen Einblick in erste Ergebnisse zum Einsatz des textbasierten Storytellings im Rahmen der Fallstudie zur Materialwirtschaft ermöglicht das nächste Kapitel.

3. Ergebnisse zum Einsatz des textbasierten Storytellings

Zur Auswertung der Fragebögen zu Motivation und CL wird ein ungepaarter t-Test herangezogen. Nicht alle Variablen sind normalverteilt, jedoch bietet der Test aufgrund der Stichprobengröße von mehr als 30 Proband:innen je Gruppe eine ausreichende statistische Power (Kubinger et al. 2009). Einen Überblick über die Zusammensetzung der Stichproben hinsichtlich Verteilung der Geschlechter und Studiengänge liefert Tab. 1.

Tab. 1: Stichprobenbeschreibung

Art der Fallstudie		Geschlecht (in %)			Studiengang (in %)						
	n	w	m	d	BA WiWi	BA WiPäd	MA BWL	MA VWL	Dipl WInf	Dipl WIng	Sonst.
Original	80	41,3	57,5	1,3	48,8	0,0	17,5	0,0	18,8	13,8	1,3
4C/ID	55 [52]	45,5	54,5	0,0	29,1	1,8	25,5	1,8	25,5	14,5	1,8
Gesamt	135 [132]	43,0	56,3	0,7	40,7	0,7	20,7	0,7	21,5	14,1	1,5

Die Stichprobe zeigt, dass die Verteilung der Geschlechter in beiden Gruppen etwa ähnlich ist. Jedoch zeigen sich Unterschiede hinsichtlich der Verteilung der Studiengänge. In der Kontrollgruppe dominieren die Studierenden des Bachelorstudiengangs Wirtschaftswissenschaften. In der Experimentalgruppe hingegen ist das Verhältnis zwischen den Studiengängen Bachelor Wirtschaftswissenschaften, Master Betriebswirtschaftslehre und Diplom Wirtschaftsinformatik recht ausgeglichen. Der Unterschied zwischen den Stichprobengrößen der einzelnen Kohorten ist darauf zurückzuführen, dass insbesondere in den ersten beiden Erhebungszeiträumen (WiSe 2022/23 und SoSe 2023) Studierende nach der Corona-Pandemie wieder ohne Einschränkungen an Präsenzveranstaltungen teilnehmen konnten. Die Veranstaltung war daher überdurchschnittlich stark besucht. Zudem haben einige Proband:innen nach Bearbeitung der Fallstudie nicht an der Postbefragung teilgenommen. Daher unterscheiden sich die Stichprobengrößen für die aktuelle Motivation (Erhebung im Pretest) und den CL (Erhebung im Posttest) marginal.

Tab. 2 liefert einen ersten Einblick in die Ergebnisse für die Fallstudie zur Materialwirtschaft.

Tab. 2: Ergebnisse der Erhebung zum Einsatz der Fallstudie Materialwirtschaft

Faktor	Art der Fallstudie	n	M (SD)	T	df	p (α=0,050)
Motivationsfaktoren						
Interesse	Original	80	3,10 (0,59)	-2,076	133	0,040
	4C/ID	55	3,32 (0,65)			
cognitive load						
extraneous load	Original	80	2,41 (0,80)	4,725	130	<0,001
	4C/ID	52	1,81 (0,55)			
germane load	Original	80	3,08 (0,76)	-2,845	130	0,005
	4C/ID	52	3,47 (0,74)			

Die Auswertung der Ergebnisse zeigt, dass der erste Iterationsschritt bereits positive Effekte bewirkte. Die für den Einsatz des Storytellings relevanten Faktoren Interesse und germane load zeigen signifikante Unterschiede zwischen den beiden Gruppen. Der signifikante Unterschied im Motivationsfaktor *Interesse* bestätigt die Annahme, dass durch Storytelling ein situationales Interesse geweckt werden kann. Der *germane load* beschreibt die kognitiven Ressourcen, die die Lernenden zum Aufbau von Schemata einsetzen. Dabei gilt, je höher der germane load, desto mehr mentale Kapazitäten investieren die Lernenden in den Aufbau neuer Wissensstrukturen. Damit bestätigt sich die theoretisch hergeleitete Annahme, dass Storytelling die Lernenden bei der Verarbeitung von Informationen unterstützen kann. Zudem zeigt sich ein signifikant geringerer *extraneous load* (durch die Gestaltung der Lernmaterialien verursachte kognitive Belastung). Im Vergleich zur Kontrollgruppe empfinden Proband:innen, die die überarbeitete Fallstudie nutzen, diese als deutlich weniger kognitiv belastend. Zurückzuführen ist dieser Effekt auf die Überarbeitung der Formatierung der Fallstudie (Ott 2023), die es den Lernenden erleichtert, die Anweisungen in der Fallstudie zu verarbeiten.

Im Gegensatz dazu steht das Ergebnis des Wissenstests. Grundsätzlich kann mit einem p-Wert von 0,048 ein signifikanter Unterschied zwischen Pre- und Post-Test nachgewiesen werden (Rogas & Ott 2024). Damit ist der Einsatz der Fallstudien grundsätzlich als lernwirksam zu bewerten. Jedoch weisen die Gruppen hier keine signifikanten Unterschiede auf. Zurückzuführen ist dies auf Inhalt und Umfang des Wissenstests. Daher erfolgt zusätzlich eine Auswertung des Fallstudienmonitors, um die Entwicklung der beruflichen

Handlungskompetenz beurteilen zu können. Der Fallstudienmonitor vergleicht die Eingabe der Lernenden mit erwarteten Werten. Hier zeigt sich eine deutliche Verbesserung durch die Fallstudienüberarbeitung (Tab. 3).

Tab. 3: Auswertung des Fallstudienmonitors - Anzahl der Abbrüche, Fehler und Warnungen

Art der Fallstudie	Warnungen absolut	Warnungen relativ	Fehler absolut	Fehler relativ	Abbrüche absolut	Abbrüche relativ
Original (n=43*)	69	1,6 pro Person	102	2,4 pro Person	32	82%
4C/ID (n=76*)	137	1,8 pro Person	105	1,4 pro Person	21	28%

*Stichprobe umfasst alle bearbeiteten Fallstudien (ab SoSe 2023), unabhängig von Teilnahme an Begleitstudie

Die im Monitor als *Fehler* bewerteten Eingaben können durch die Überarbeitung der Fallstudien nahezu halbiert werden. Darüber hinaus sinkt die *Abbruchquote* der Lernenden stark ab. Eine Reduzierung der als *Warnungen* erfassten Fehleingaben ergibt sich dagegen nicht. Die in Tab. 4 dargestellte Detailbetrachtung ausgewählter Prozessschritte verdeutlicht, dass insbesondere im ersten Prozessschritt in der Originalfallstudie häufiger Fehler gemacht werden.

Tab. 4: Auswertung des Fallstudienmonitors - Detailbetrachtung ausgewählter Prozessschritte

Prozessschritt	Art der Fallstudie	n*	Bearbeitungsstatus in % Erfolg	Warnung	Fehler	Abbruch
1 - Anlegen Lieferant	Original	35	57,1	17,1	25,7	0,0
	4C/ID	52	84,6	7,7	7,7	0,0
7 - Anlegen Anfrage	Original	35	51,4	0,0	28,6	20,0
	4C/ID	52	80,8	0,0	10,0	0,0
10 - Anlegen Bestellung mit Bezug auf Anfrage	Original	26	84,6	0,0	0,0	15,4
	4C/ID	52	78,0	0,0	8,0	14,0
21 - Buchen der zweiten Lieferantenrechnung	Original	10	40,0	50,0	0,0	10,0
	4C/ID	40	57,5	37,5	0,0	5,0

*n ergibt sich aus der Anzahl der Proband:innen, die den jeweiligen Prozessschritt bearbeitet haben

Im Schritt 7 brechen bereits 20 % der Studierenden die Fallstudienbearbeitung ab, 29 % geben fehlerhafte Daten ein. Als besonders kritisch zeigt sich der Prozessschritt 10, welcher auch in der überarbeiteten Fallstudie erstmalig zu Abbrüchen bei den Lernenden (14 %) führt. Wir definieren die Fallstudie als abgeschlossen, sofern Schritt 21 erfolgreich bearbeitet wurde. Dies ist für 9 Teilnehmende der Originalfallstudie (25,7 %) und 38 nach der Fallstudienbearbeitung (73,1 %) der Fall. Aufgrund dieser höheren Erfolgs- sowie der geringeren Fehlerquote lässt sich darauf schließen, dass die überarbeitete Fallstudie besser zur Entwicklung beruflicher Handlungskompetenz, insbesondere digitaler Grundfähigkeiten, beiträgt.

4. Diskussion

Die vorliegenden Ergebnisse zeigen deutlich, dass die Überarbeitung der Fallstudien den von uns theoretisch hergeleiteten Annahmen gerecht werden. Sowohl für den im Kontext des Storytellings entscheidenden Motivationsfaktor Interesse, als auch für den entscheidenden Faktor des CL, den germane load, konnten signifikante Verbesserungen erzielt werden. Kritisch zu betrachten ist an dieser Stelle die Zusammensetzung der Stichprobe hinsichtlich des Studienganges. Hier muss geprüft werden, ob die Unterschiede nicht eventuell auf den Studiengang zurückzuführen sind. Gleiches gilt für die grundsätzliche Motivation der Lernenden im Studium, die ebenfalls als Kontrollvariable erhoben wurde.

Fehleingaben und vorzeitige Abbrüche bei der Bearbeitung der Fallstudie konnten deutlich reduziert werden. Im Sinne der Handlungskompetenz interpretieren wir diese Ergebnisse so, dass die Studierenden ihre Fähigkeit, in komplexen (Problem-)Situationen selbstorganisiert handeln zu können, verbessert haben. Der Einsatz von Storytelling in der Hochschullehre wird von uns daher als zielführend eingeschätzt. Weitere Forschung kann hier anknüpfen und untersuchen, ob sich beim Einsatz der Interventionen im Kontext anderer Zielgruppen die gleichen Effekte zeigen. Potentielle Zielgruppen sind dabei alle jene Lernenden, die in ihrem beruflichen Alltag in absehbarer Zeit mit dem Einsatz von ERP Systemen bzw. SAP S4/HANA konfrontiert werden. Sinnvolle Kooperationspartner sind daher berufsbildende Schulen oder berufliche Gymnasien. Aber auch im Unternehmenskontext, wie beispielsweise dem Onboarding neuer Auszubildenden, ist der Einsatz der Intervention denkbar.

Im nächsten Iterationsschritt gilt es zu untersuchen, ob der Einsatz der GN einen zusätzlichen Mehrwehrt hinsichtlich der Entwicklung von Motivation und kognitiver Belastung erzielt. Gleiches gilt für den Einsatz der Mini-Planspiele. Die Planspiele wurden bereits im Rahmen eines Pilotprojekts auf die Eignung zur Wissensvermittlung und auf die Wechselwirkung zu Fallstudien untersucht (Häusler et al. 2023). Eine Analyse mit Blick auf Motivation und CL mit Hilfe des DBR erfolgte bisher jedoch nicht. Da es sich beim Einsatz des Serious Games, wie beim Einsatz der überarbeiteten Fallstudien, um die Erprobung eines Lehr-Lernsettings handelt, ist das Untersuchungsdesign ebenfalls anwendbar. Es stellt sich die Frage, ob es durch die vorangestellten Spiele ähnliche Effekte bei der Bearbeitung der Fallstudien auftreten.

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NAVIGATING RESEARCH PATHWAYS
The RISE Framework for Guided Research Interest Exploration in Higher Education

S. Kruschel, A. Rottensteiner & C. Ploder
MCI – The Entrepreneurial School, Innsbruck, Austria

Abstract: As students approach the final phase of their study program, they stand at a critical juncture of finding a thesis topic that not only holds scientific relevance but also ignites their interest and intrinsic motivation. Furthermore, writing a thesis on a certain topic could serve as a first step towards a professional or academic career, while considering the possible societal impact and applying individual academic strengths. Therefore, the aim of this paper is to describe the Research Interest Scope Explorer (RISE), a framework connecting the mentioned areas and supporting students in navigating the complexities of finding a personal research interest. To do so, the authors decided to follow a methodological process rooted in a design thinking approach. After an initial needs assessment based on a comprehensive literature review combined with stakeholder interviews, the development of the single framework components was conducted. Presenting the preliminary framework to an expert group, revealed minor shortcomings mainly in the structure of the framework components, that was improved before testing the RISE prototype in a classroom setting. The final phase involved gathering qualitative feedback from participating students to further enhance the framework. The validated RISE framework provides a hands-on tool for lecturers to support their students and facilitate the process of finding a research interest. Although the framework will not generate specific topics, it still serves as a valuable foundation upon which students can build their thesis topics, enabling a more guided and reflective selection process.

Keywords: Research Interest Development, Design Thinking in Education, Thesis Topic Selection, Academic Motivation Frameworks

1. Introduction

In higher education the process of developing a fitting personal research interest often marks the transitions from a student's to a researcher's perspective. This not only significantly shapes the student's academic trajectory but could also build up the foundation for a future professional or academic career. As developing a fitting research interest can be daunting, balancing scientific relevance, personal interest, career aspirations and the potential societal impact can be even a bigger challenge. Therefore, this paper introduces the Research Interest Scope Explorer (RISE) framework. For the purposes of this paper, we define "framework" as a structured guide that facilitates a step-by-step process, similar to a "guided tour". This framework is designed to support students in identifying and refining their research interests by connecting the above-mentioned components: scientific relevance, personal interest, career aspirations and the potential societal impact. By proposing a structured and reflective approach, the RISE framework seeks to moderate and facilitate the complex task of research interest development, while increasing students' engagement and the quality of their academic study. Although this paper is focusing on the application of RISE on a Bachelor level, it can be adapted for Master's or Doctoral Students.

To address the development, application and validation of the RISE framework, this paper is structured into six chapters. After reviewing the literature on research interest, the methodology chapter will focus on the process applied during the development of the RISE framework. The detailed description of the RISE framework will be followed by the implementations and testing chapter, discussing the in-class application and qualitative feedback from students and experts. The paper will be concluded by summarizing the findings and suggesting further research directions to contribute to the field of facilitating the process of research interest development.

2. Literature Review

The authors decided to conduct a systematic literature review following the methodological approach outlined by Snyder (2019). The primary research question guiding this literature review was: "How can a structured framework facilitate the development of research interest among higher education students?". Based on this research question, comprehensive searches were performed across multiple academic data bases including Google Scholar, Scopus and Science Direct, utilizing precise search strings such as "research interest development", "higher education student motivation" and "design thinking in education". This approach assured a thorough examination and synthesis of already existing literature relevant to this study.

According to Hensel (2012) research can be seen as a fundamental process in supporting the development of critical competencies such as innovation, creativity, analytical thinking and problem solving. These competencies are crucial for undergraduate students in order to address issues in today's society. Although being aware of the importance, undergraduate research often lacks in comprehensiveness due to various challenges.

One major challenge students are facing is the difficulty of choosing and narrowing down their research topic (Todd et al., 2006). This complex task often leads to frustration, anxiety and lack of confidence, ultimately decreasing students' interests and motivations in doing research (Nind et al., 2020). Dorji (2020) furthermore states that many curricula often overlook and underestimate teaching the foundational process of finding a fitting research focus. This is often seen as a skill that should be acquired by students individually. Students without any guidance in the topic selection process often fail to see the relevance of their studies and tend to lose interest in their research area (Ali & Zayid, 2022; Bocar, 2009).

Projecting these findings to the Self Determination Theory (SDT) by Ryan & Deci (2000) it can be stated, that finding a right research focus could have significant impact on intrinsic motivation, extrinsic motivation, self-determination and autonomy in student's research. Engaging in an activity because it is interesting leads to quality learning and creativity. A research interest that is fascinating, therefore increases intrinsic motivation and the quality of scientific work. Even if a topic is chosen due to external influences (e.g. career goals or supervisor), it is important that this topic is still personally relevant. Identifying with the topic and integrating personal values and goals will lead to a deeper and more self-determined commitment. Notably, supporting autonomy - the feeling of making decisions about the individual research interest - is crucial for promoting both intrinsic and extrinsic motivation. A topic that was chosen by students themselves and that fits in with their long-term goals and values will boost motivation and perseverance. To respond to these challenges and support students in finding their research interest, several different frameworks were developed in recent years.

One example is the VITAE Research Development Framework (RDF) mainly focusing on aligning research with career goals and professional development and helping researchers to design action plans for career progressions. (VITAE, 2011). Whereas Bray & Boon (2011) highlight the structured, reflective and individualized approach, they criticize the initial complexity and usability of the framework. Although other tools like interest inventories or different career counseling techniques could help to align students' research with personal interests and intrinsic motivation a holistic approach integrating and addressing multiple influencing factors is missing.

3. Methodology

The development of the RISE framework was based on a design thinking methodological approach. This user centered design process ensured that the final outcome was tailored to meet different needs of stakeholders (students and faculty), proposing a practical and effective tool for research interest exploration. The design process followed the five stages, proposed by Plattner et al. (2011): emphasize, define, ideate, prototype and test. The first phase focused on a comprehensive literature review and stakeholder interviews with students and faculty in order to collect insights into challenges and needs directly related to research interest explorations. Interviews were conducted with 10 students and 4 faculty members from various backgrounds. Participants were selected to represent a diverse range of perspectives and were chosen both randomly and through peer recommendations. Key findings indicated that students often struggle with narrowing down broader interests into more specific research topics. This finding can be further supported by Todd et al. (2006). Furthermore, students stated a need for a facilitating process that could help to integrate their personal interests into their research focus exploration. Based on this collected evidence, the different components of the RISE framework were collected and further defined. Each component was designed in a way that it will guide students to reflect on their motivations and goals. The design process included several different iterations of the framework, integrating valuable feedback from an expert group consisting out of selected students and faculty members.

4. Description of the RISE framework

The RISE framework comprises four key components that will guide students through a structured process of reflection, connection, prioritization and formulation. The framework will guide students through an interactive process including the following stages:

1. Reflect on personal interests, academic strengths, societal impact and career aspirations.
2. Draw possible connections between ideas from these areas to identify potential research paths.
3. Prioritize and define the most significant research paths.
4. Formulate a research mission statement that integrates the identified research paths.
5. Present and refine the research ideas implementing peer feedback.

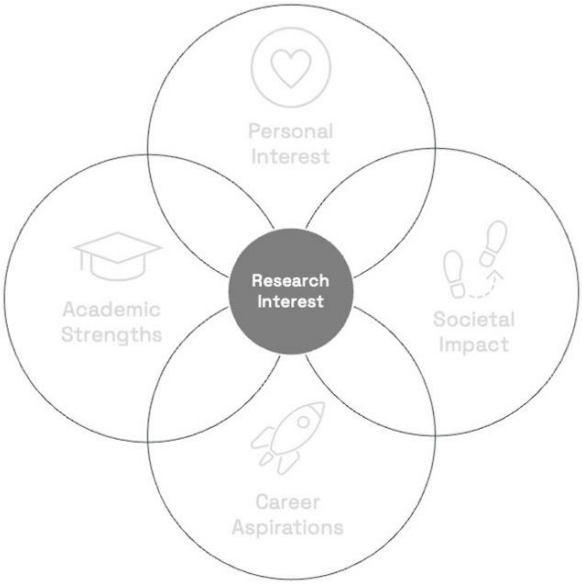

Fig. 1: RISE framework

As depicted in Fig. 1, the four different areas intercept at the research interest. For a holistic research interest it is relevant to balance all four key components. Balancing the components means ensuring that each of the four key areas (personal interest, academic strengths, societal impact, and career aspirations) is given appropriate consideration to avoid overemphasis on any single area. An overrepresentation of one component in the RISE framework can lead to imbalances such as lack of scientific rigor, personal disengagement, impractical research scope, or overly pragmatic topics lacking innovation.

To get a deeper understanding of the key components, each of the factors is explained in more detail.

4.1. Personal interest

Personal interest refers to topics and activities that excite and motivate. Reflecting on these personal interests will include identifying different subjects that students are passionate about. This should consider questions like “What inspires me?” or “What do I enjoy reading and talking about?”.

4.2. Academic Strengths

Academic strengths are areas of study where one excels and enjoys working on. Identifying these strengths helps to focus on skills that guide towards research areas likely to lead to success. Some supporting questions could include “In which subjects have I performed well?” or “What types of projects have I found the most enjoyable?”

4.3. Societal Impact

Whereas the previous components were quite specific and personal, this part of the RISE framework encourages students to think about broader implications of their research and how it could potentially address societal needs and challenges. Questions that should be considered

are “What societal issue am I passionate about?” and “How can my research make a positive impact?”.

4.4. Career Aspirations

This section relates to the professional goals students aim to achieve. Aligning research interests with career aspirations ensures relevance and benefits future career paths. This should consider guiding questions like “What are my long-term career goals?” and “How can my research support my professional development?”.

5. Implementation and Testing

The RISE framework was implemented and tested in a classroom setting involving 51 students from a business informatics bachelor study program. This included interactive sessions where students applied the framework in order to identify and refine their research interest. On average, it took students approximately one day to reach an initial state of reflection. Depending on the depth of reflection the full completion of the framework and identification of the research interest took several weeks. Qualitative feedback was gathered during focus groups including participating students, conducted after the implementation of the framework. Some of the key themes identified in the focus groups included enhanced clarity and focus, increased motivation, practical applications and usefulness as well as the structured and reflective approach of the framework. Especially the focus on the personal interest and intrinsic motivation helped students to feel more engaged and motivated to develop their research focus. One of the major drawbacks mentioned in the qualitative feedback was that some of the students perceived the overall process as too time consuming. Streamlining certain aspects and phases of the RISE framework could make it less cumbersome. While the peer feedback during the last phase was generally appreciated, there was a high variability in the quality of the received feedback. Providing clear guidelines for giving and receiving feedback could increase the quality and the value of the feedback.

6. Conclusion

The RISE framework can be seen as a valuable tool for faculty and students to facilitate a guided and reflective process for research interest exploration. The specific outcome of the RISE framework is a well-defined and personally meaningful research mission statement. Although it does not directly generate specific research topics, it provides a solid foundation for students to e.g. build their thesis topics on. Especially the interactive and still structured approach will help students to identify their research interest and furthermore increase motivation and engagement. Future research could include refining the framework based on feedback collected in different educational contexts. Additionally, the integration of digital tools could further enhance the experience of applying the framework.

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IIoT Architecture for Smart Manufacturing Reporting based on a FESTO Didactics System

V. Quoika[1], M.R. McCormick[2], T. Wuest[2], A. Fink[1]
[1]Helmut-Schmidt-University, Hamburg, Germany
[2]West-Virginia University, Morgantown, United States of America

Abstract: Smart manufacturing and Industry 4.0 integrate digital information from various sources and locations to drive manufacturing within a connected ecosystem. This paper presents an IT architecture for integrating sensor data from production equipment of a FESTO® Didactics production system and shows how Industrial Internet of Things (IIoT) data can be evaluated in SAP® Analytics Cloud for university education. The aim of using an IIoT showcase in higher education to assist students in error detection, process reliability and quality improvement within the IIoT context. The goal of educating students with a practical example of IIoT and smart manufacturing is to encourage innovative thinking and strategic insights, demonstrating how technology extends beyond automation to create and transform business models. Furthermore, this paper assesses an IT architecture for integrating IIoT data within an SAP® landscape, highlighting the potential for improved production monitoring and data analytics.

Keywords: Smart Manufacturing, Industrial Internet of Things, Manufacturing Execution System, Production Reporting, SAP Analytics Cloud

1. Introduction

Teaching the Industrial Internet of Things (IIoT) and smart manufacturing is crucial for professional education, for fostering innovation, and for training the future workforce (Wang, 2014). The fourth industrial revolution (Industry 4.0), which is characterized by automation and data exchange in manufacturing technologies, cyber-physical systems, IIoT, cloud computing and artificial intelligence, is contributing to competitive and improved production processes through digital factories (Hermann et al., 2016). The objective of Industry 4.0 and smart manufacturing is to enhance industrial production by advanced (often data-intensive) technologies in order to improve efficiency, flexibility and productivity and create responsive applications in shop floor operations (Thoben et al., 2017).

Enterprise Resource Planning (ERP) systems can be considered as the IT backbone of many organizations which integrate various organizational parts into a single system and play a crucial role in modern enterprise management (Shaul & Tauber, 2013). Integrating shop floor machinery into the broader landscape of business IT architecture can be challenging in practice. One challenge in integrating production data and IIoT data into a larger business IT architecture is the interoperability issue posed by proprietary manufacturing systems (McCormick et al., 2024). To understand the scope of the problem, production processes can be viewed as part of a larger enterprise model.

		Business Map				Information Map		Ecosystem Map	
		Motivation	Organ.	Function	Process	Application	Data	Technology	Network
Corporate Management (strategic)	1								
Area Management (tactical)	2								
Workplace (operational)	3		ORG	FBD	BPMN	EPC	ERM	UML	UML
Compliance	4								

Figure 1: Enterprise modeling in the field of manufacturing with the Enterprise Online Guide framework (Scheruhn et al., 2021)

Production systems can be viewed as socio-technical systems, which combine a sociological and a technical element (Barley, 1986; Mumford, 2006). There are various modeling semantics that provide an overview of an organization's enterprise architecture (EA), such as the EA framework (Shah & Kourdi, 2007; Jonkers et al., 2006). When creating an enterprise model of this socio-technical system, it is important to consider not only the technical, but also the business context. The Enterprise Online Guide (EOG) integrates different models (Scheruhn et al., 2021). The eight submaps illustrate the robustness of production business operations, human-machine integration, and networking within the enterprise (see Figure 1), of which the data and application view was particularly helpful for this paper. Another useful model for evaluating the overall architecture is the TOGAF® standard (Josey et al., 2018), which provides guidelines for defining "architecture" based on the ISO/IEC/IEEE 42010:2011 standard.

In this paper, we first present the lab setup of the FESTO® Didactics system, for which we will later build a production reporting system. Following this, we provide an overview of manufacturing execution systems (MES) and interface manufacturing execution system (IMES) (Govindaraju & Putra, 2016), which collect and summarize data from the shop floor. In Section 3, we propose three solution architectures for integrating production data into an SAP® analytics environment. In Section 4, we discuss the key performance indicators (KPIs) that we used in the first academic case study for higher education. Finally, in Section 5, we discuss potential extensions of the prototype system.

2. FESTO Didactics Smart Manufacturing Testbed at West-Virginia University

To create a smart manufacturing reporting system, we consider a FESTO® Didactics system with eight workstations that are connected by conveyor belts and simulate the production process of a cell phone case. The FESTO® workstations are equipped with sensors that collect data for their programmable logic controllers (PLC) across the eight production modules:

(i) CP-AM-MAG-FRONT (dispense front magazine): Feeds front covers into the production line.
(ii) CP-AM-MEAS (measuring): Performs quality assurance and measures optical signals.
(iii) CP-AM-DRILL (drilling): Drills parts.
(iv) CP-AM-MAG.BACK (magazine): Supplies the back cover of the part.
(v) CP-AM-MPRESS (muscle press): Presses the front and back parts together with a pneumatic press.
(vi) CP-AM-HEAT (heating tunnel): Heats the workpieces through thermal processing.
(vii) CP-AM-TURN (turning): Flips the workpiece.

(viii) CP-AM-OUT (output): Removes the final workpiece from the production line.

FESTO® provides a state-of-the-art laboratory that provides students and researchers with hands-on experience and practical training in manufacturing technologies, automation systems, and Industry 4.0 concepts. Each station is controlled by a PLC, which provides a human-machine-interface for monitoring the machine status and identifying potential issues. This setup allows students to learn about automated manufacturing processes and gain practical experience in an Industry 4.0 environment encompassing cloud computing, cyber-physical systems, and big data. Additionally, we linked the FESTO® Didactics system with a FESTO® energy measurement box[5] and two Shelly smart meters[6] in order to monitor energy consumption in our production reporting application.

3. MES and Production Reporting

Since the mid-1990s, an increasing number of manufacturers have begun to bridge the information gap between production and commercial levels, making the MES an important component of Industry 4.0 (Fatima et al., 2020). An MES is a computerized system used to monitor, control, and optimize production in manufacturing companies by collecting, analyzing, and managing real-time data from various sources (Saenz de Ugarte et al., 2009). Within an EA, the MES is roughly situated between production machinery and the ERP system (Govindaraju & Putra, 2016), incorporating data from both the business and production order sides. In the automation pyramid, which provides an overview of bottom-up data integration in a production environment, from the production process at level 1 to business and logistics planning at level 4 of the pyramid (done by ERPs), the MES is considered an integral level 3 (Körner et al., 2019).

Figure 2 illustrates MES components that aggregate data from actuators and sensors, from the Supervisory Control and Data Acquisition (SCADA) system, Distributed Control Systems (DCS), PLCs, and other smart devices (Shojaeinasab et al., 2022). Additionally, historical shop floor data are often stored in a database (Govindaraju & Putra, 2016). An optional component, the Interface MES, gives easy access to production data for real-time shop floor applications (Mantravadi et. al, 2020). Overall, the Manufacturing Enterprise Solutions Association has identified 11 functions of MES systems (Shojaeinasab et al., 2022), namely: resource allocation and status, operations scheduling, product unit dispatching, documentation and document control, data collection and acquisition, labor management, quality management, process management, maintenance cycle planning, product tracking and performance analysis. Thus, MES is an integral part of data collection within the EA. However, in practical applications, shop floor systems are often still closed, proprietary solutions that are not connected or interchange data.

In practical industrial applications, SAP® offers a native SAP® Manufacturing Integration and Intelligence Application (SAP® MII) that extracts IIoT data and improves transparency

[5] FESTO® energy measurement box (https://www.festo.com/us/en/p/energy-measurement-box-id_PROD_DID_8129208/?page=0)

[6] Shelly Plus Plug US for PLC power supplies and for the heating element (https://www.shelly.com/en-us/products/shop/shelly-plus-plug-us)

throughout the production process[7]. Concerning MES, SAP® recommends using SAP® MII in conjunction with the SAP® Manufacturing Execution Suite[8]. To implement these applications, we need to design an architecture for IIoT data that exchanges data with the shop floor. The architecture that is developed in the next chapter can also be seen as a stepping stone for data exchange with SAP® MII or SAP® ME systems.

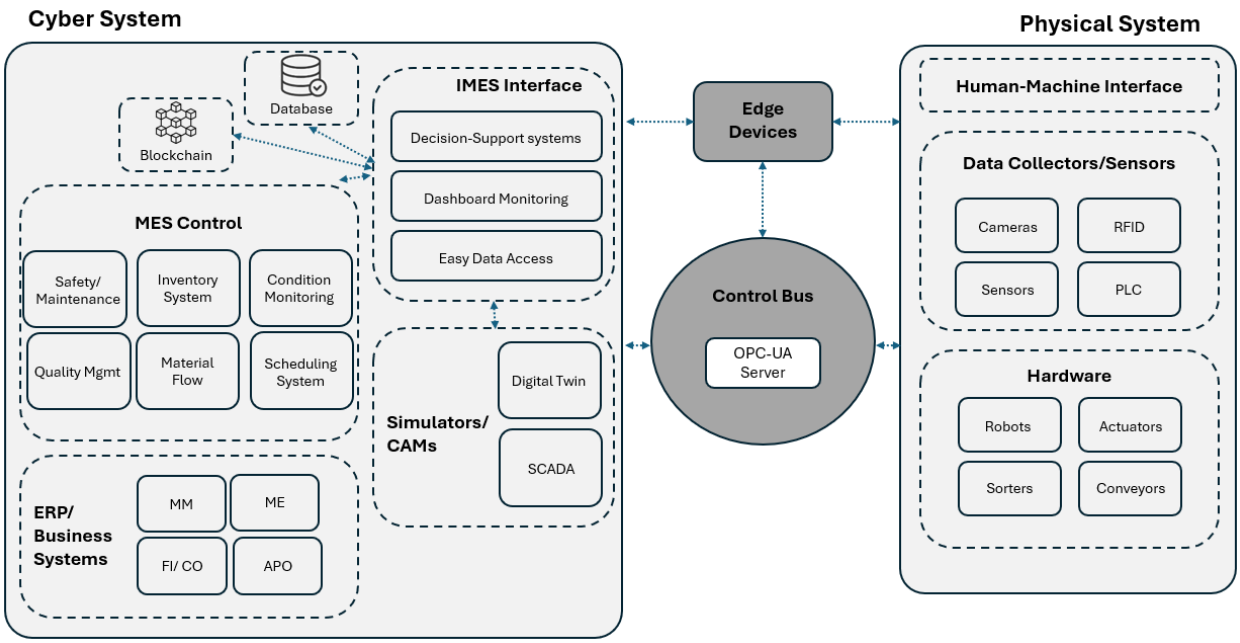

Figure 2: Conceptual model of the components of an IMES system (Shojaeinasab et al., 2022)

4. Suggested Architectures for Integrating FESTO® Didactics Data

For production reporting purposes, we suggest selecting data points from the PLCs used to control the production equipment and integrating data from the energy meter into a data model. This can be achieved through the use of an ETL procedure (extract, transform, and load), in which different data objects are persistently modeled (Liebenberg & Jarke, 2023). We apply a traditional data warehouse modelling approach, in which the data is filtered, harmonized, aggregated, and enriched in a data mart (Baars & Kemper, 2021). However, analyzing sensor data can be challenging due to differences in measurement frequency and data formats (i.e., state- vs. event-based). In this section we introduce three architecture options. According to the TOGAG® architecture standard we aspire for the quality principles of understandability, for simplicity of operations, robustness, completeness, consistency and stability of data delivery (Josey et al, 2018). Furthermore, in our test environment, we require to expand the system with further equipment, measuring points, source systems, KPIs and dashboards.

[7] SAP Manufacturing Integration and Intelligence (MII) (https://help.sap.com/docs/sap_manufacturing_execution /e1adc70af32241619335c8768a892edb/04510820335f4e129df327de58689a22.html)

8 SAP Manufacturing Execution (ME) (https://help.sap.com/docs/sap_manufacturing_execution /e1adc70af32241619335c8768a892edb/04510820335f4e129df327de58689a22.html)

We consider three architectures for the solution design:

a. **Reporting on middleware data** is done based on data from a MQTT broker. This means that data used for orchestration of the shop floor is directly captured and exchanged on the middleware as a central point and transferred to production analytics systems.
b. **Reporting directly on FESTO® MES access database**. In the FESTO® MES, entries of production order and customer order entries, as well as necessary production steps, are maintained. Master data are stored permanently here, but transactional data are automatically deleted shortly after the production ended. Because the FESTO® database is not for long-term storage, we need to transfer data during the production process to keep historical data.
c. **Data integration via a "data fabric/ data mesh"** which is an end-to-end integration of diverse source systems and cloud environments into a single cloud based on the data-as-a-service (data-as-commodity) assumption (Hechler et al., 2023). The SAP® DataSphere exemplifies such a business data fabric, which even provides AI-based data cataloging and AI data governance.

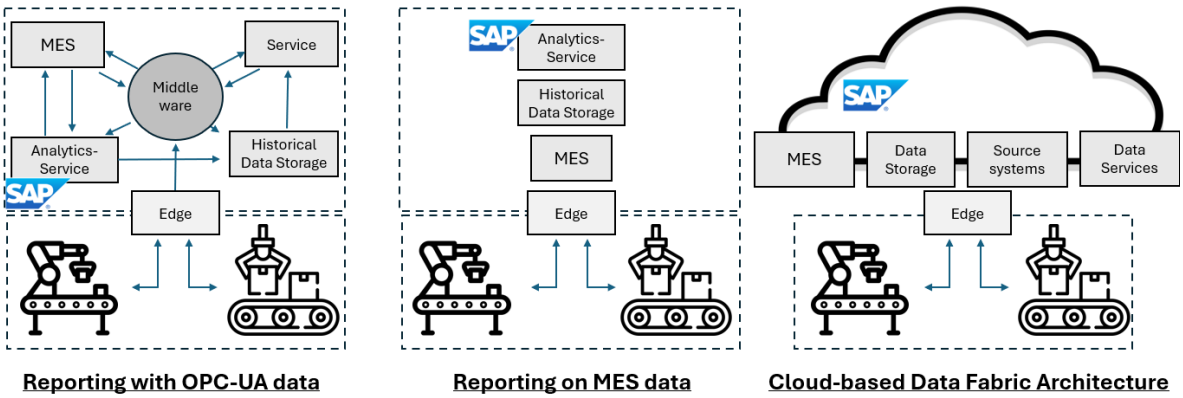

Figure 3: Three architecture options for integrating IIoT data to SAP production reporting

To integrate data from the FESTO® Didactics system into an SAP® environment, we evaluated the three architectures for a production reporting case study (Figure 3). Whereas option (b) of reporting on MES data offers the most direct approach to accessing production data, we found it challenging to expand the system with additional measuring points from sensors or IIoT devices (like the energy meter). Option (a) involves collecting data from the middleware. This setup allows access to sensor data from the FESTO® Didactics PLCs and can be extended with additional devices which broadcast directly to the MQTT middleware (Hunkeler et al., 2008; Billey & Wuest, 2024). The Message Queuing Telemetry Transport (MQTT) open publish/subscribe protocol is designed to provide reliable transmission for telemetry applications. The protocol is designed on TLS for communication security between entities and retransmits the sequenced data packet until there is an acknowledgement from the receiving party (RFC 9431).

To collect historical shop floor data from the *Eclipse Mosquitto* MQTT broker, we used a Python program to load data into a MySQL database using Pandas, SQL.Connect and SQLAlchemy. We log two timestamps, one for the event observation at the PLC and the other for the database transaction at the server. Both events are encoded according to the ISP 8601 standard in Coordinated Universal Time (UTC) instead of the Unix timestamp format. The

MySQL server can be used as data source for SAP® Analytics Cloud (when using the SAC Simple Deployment Toolkit). For the case study, we imported shop floor data in CSV format.[9]

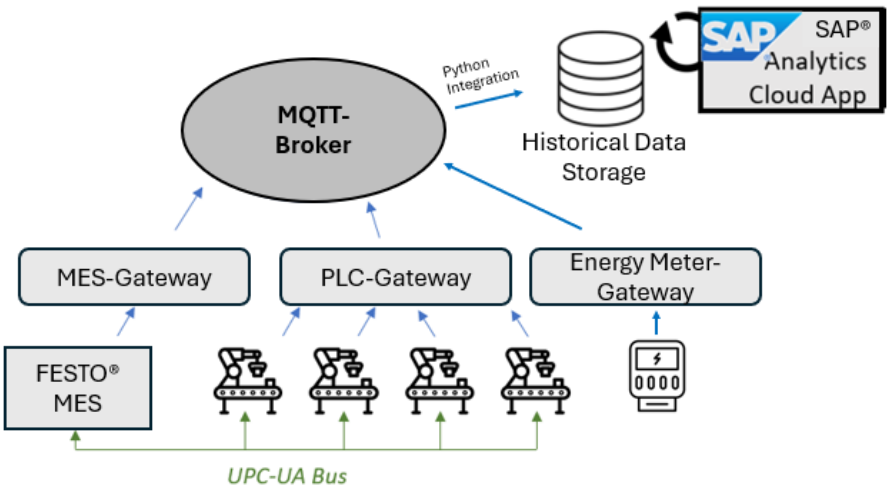

Figure 4: Solution architecture for production reporting with SAP® Analytics Cloud

The solution architecture setup is displayed in Figure 3. Sensors from the FESTO® Didactics production environment operate via Ethernet connection, whereas the Shelly energy meters operate via Wi-Fi. If multiple production lines, web services or cloud-based systems were involved, or if data integration from a supply chain network was required, a data fabric architecture in the cloud (option c), supported by SAP® DataSphere, would be the preferred choice. For the testbed reporting, only SAP® Analytics Cloud reporting resides in the cloud, while the majority of data remains on-premises (i.e., within the university network).

5. Development of Production Reporting KPIs with SAP® Analytics Cloud

The production KPIs need to be aligned with department goals and the overarching company strategy, including corporate vision, market positioning or financial indicators (Khan & Shah, 2011). Ante et al. (2018) suggest that financial and non-financial KPIs can be disaggregated into departmental KPIs. In the area of production, KPIs should be designed to achieve high productivity, availability, and quality (Gendre et. al, 2016). Banker et al. (1993) categorize production KPIs in “quality”, “productivity”, defects”, “schedule compliance” and “machine breakdown” with the goal of promoting “continuous quality improvement”. In the following section, we describe two analytics applications based on production data from a FESTO® Didactics system. The two dashboards are included in the annex.

The first dashboard gives an overview of production planning data, such as production time and lead time for each production order. It evaluates all production order positions by extracting planned and actual timestamps for each workstation from the MQTT broker. Additionally, we calculated during the ETL procedure the transport time compared to the production time of each production order. This measure allows us to assess the efficiency of transport routes within the smart manufacturing testbed and identify production process bottlenecks.

[9] The full data set can be provided upon request

The solution architecture also allows the collection of sensory data from individual workstations, including the pneumatic muscle press (CP-AM-MPRESS) and the heating tunnel (CP-AM-HEAT). For the second dashboard, we evaluated the energy consumption of the energy-intensive heating tunnel workstation in comparison with the entire FESTO® Didactics system. In a previous study, the CP-AM-HEAT workstation was used to create an energy digital twin using data from this FESTO® workstation (Billey & Wuest, 2024). The second dashboard in the annex extracts the cumulative energy consumption, heating tunnel temperature, and active power in the heating tunnel from the MQTT broker and imports them into SAP® Analytics Cloud.

The data from sensors and PLCs are processed via ETL to create an online analytical processing model (OLAP) for extracting and displaying various key figures in an SAP® Analytics Cloud dashboard. This dashboard can also be used in a university context to illustrate manufacturing principles and demonstrate error detection and process reliability.

6. Discussion and Outlook

In this paper, we propose a reporting system for manufacturing data from a FESTO® Didactics system. The configuration can be used in a university setting to illustrate various key production figures and teach students to build their own evaluations. There are several promising scenarios for extending the reporting system:

- Extension of the system to SAP® ME or SAP® MII to integrate IoT scenarios into the production planning processes and enrich the MES with commercial and customer data.
- Extension with additional sensors, key figures, or dashboards.
- Modification of the current configuration into a data fabric architecture, which can be extended with multiple OPC-servers or sensors from proprietary systems.
- Application extension through the incorporation of machine learning algorithms is a potential enhancement of the functionality of existing applications. Potential scenarios include predictive maintenance and production scheduling applications.

The architecture presented in this paper has the potential demonstrates the principles of IIoT, smart manufacturing and data analytics in research and education at universities. Additionally, it is a comprehensive case study for integrating shop floor data and IIoT in analytics applications in the context of a larger SAP® enterprise architecture.

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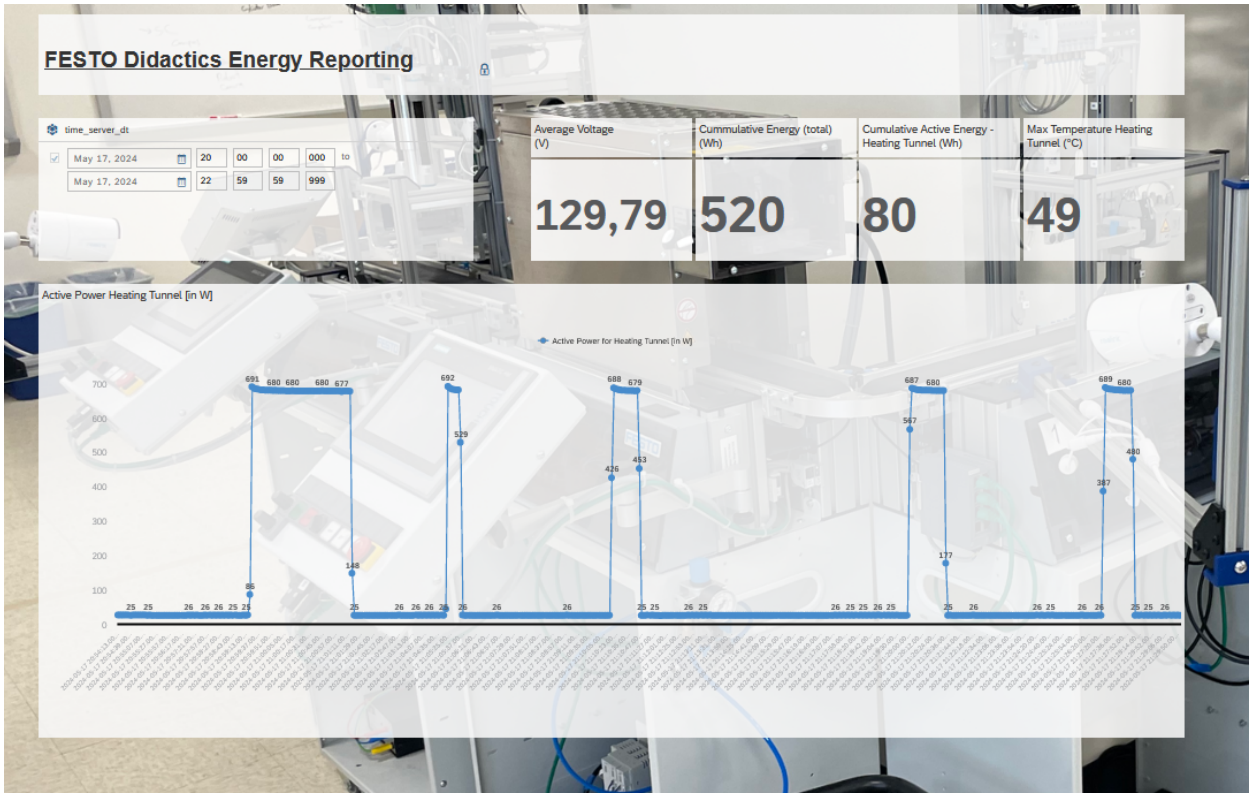
8. Annex

Annex 1: Analysis of production and transport time per FESTO® Didactics workstation



Annex 2: Reporting for energy consumption of the heating tunnel workstation and the total energy consumption of the FESTO® Didactics system

Bridging Theory and Practice - Embedding Micro learning of Enterprise Systems in University Lectures

M. Wienand, S. Seufert & R. Schütte
University of Duisburg-Essen, Essen, Germany

Abstract: Due to the digitalization, there is a growing need for specialists in organizations with competencies in enterprise systems (ES) like SAP S/4HANA. These specialists can either be trained within the organization or recruited by hiring new employees, such as university graduates. However, for graduates to develop these competencies, they need to be trained already during studies. To counter this requirement, micro learnings, where learning content is presented in short activities, could be embedded into lectures. However, there is currently a lack of guidance for embedding ES micro learning content into lectures. Towards the development of a micro learning framework based on a structured literature review and consortium research, we were able to identify 10 requirements for ES micro learning courses. Finally, we developed a framework that can serve as a guide for lecturers. The framework will be applied in university teaching for the first time in summer term 2024.

Keywords: Micro Learning, Enterprise Systems, University Lectures, E-Learning, ES Education.

1. Introduction

Competencies in using enterprise systems (ES) like SAP S/4HANA are increasingly required in organizations (Bonfield et al. 2020, Charland et al. 2010, Léger 2006, Soellner 2021). To account for this requirement, organizations are resorting to upskilling their existing staff by offering trainings to acquire the necessary skills. Conclusive to this, organizations seek those competencies in new hires, such as university graduates. Accounting to the rising need of ES-skilled graduates, many universities already attempted to integrate ES education to the curricula of corresponding study fields like business administration (about 240.000 students in Germany), information systems (about 54.000 students in Germany) and computer science (about 140.000 students in Germany) (Statista 2023), to enable students to obtain those competencies before they start their career (Soellner 2021). Due to the large number of students in these subjects, it is inherent that these lectures must be accessible on a large scale. To counteract the problems mentioned before, there have been several approaches to integrate electronic learning (e-learning) elements into large-scale university lectures (Alamri et al. 2021), also known as blended learning approach (Alammary et al. 2016, Bruff et al., 2013). To enable the provision of these competencies to a target group as large as possible we will propose a blended learning approach incorporating micro learning content on ES use into lectures. Micro learning courses are competency-based, personalized, on-demand, and shareable learning sets, that focus on special competencies and lead to the obtainment of so-called micro-credentials (Hunt et al. 2020). There is a lack of guidance in how to embed ES micro learning content in university lectures. To close this gap will develop a framework for ES micro learning content that can be applied in practice. The remainder of this paper is structured as follows: In Section 2, we elaborate the learning in the digital age. Following this, we will describe the methods used in this paper in Section 3. In Section 4, we present the results of the literature review and consortium research while developing our framework. In Section 5, we draw our conclusions

and explain our next steps.

2. Learning in the Digital Age

Learning involves the acquisition of knowledge combined with changes in behavior, attitudes, skills, habits, and feelings (Sweller 2020). To be able to recall the learned information, this information needs to be processed by working memory to finally being stored in the long-term memory (Sweller et al. 2019). Nevertheless, even though the long-term memory is assumed to have unlimited space, the working memory has only limited capacity (Miller 1956). This is supported by the implications of cognitive load theory (CLT), that states that the perceptual and cognitive system of humans has a limited capability to process information of any kind (de Jong & Jong 2010). To overcome these limitations of the working memory it is stated, that learning content should be provided in different media, as verbal and pictorial information are processed differently by the human brain (Mutlu-Bayraktar et al. 2019, Sweller 2020). Thus, to foster the learning process, learning contents should be provided in different media stimulating the different sensorical systems of the students (Sweller 2020).We understand e-learning as the use of new multimedia technologies and the internet to increase learning quality by making the access to facilities and services easier and to enable exchanges and collaborations across distances (European Commission 2001). Therefore, e-learning might be a good vehicle to support students learning processes. In times of digitalization, employees and future employees need to develop technological and technical competencies (Lang 2023). Lectures designed in traditional ways (classroom lectures) bear some downfalls, like the lack of individualization, a limited scalability and the lack of flexibility (Léger et al. 2011, Paa & Ates 2013, Schmidt et al. 2015). By using e-learning, the different predispositions of students towards learning information systems can be taken better into account by using e-learning, as the tasks can be worked on individually, and self-paced learning is fostered (Santhanam et al. 2008, Soellner 2021). Nevertheless, e-learning approaches are not only considered beneficial, but also hold some downfalls, like the lack of personal feedback, or exchange with other participants (Lai et al. 2020). As the traditional lectures as well as the e-learning approach obtain shortcomings, an integration of both approaches seems reasonable and beneficial. A combination of e-learning and traditional lectures is called blended learning and is already used in university context (Alamri et al. 2021). Nevertheless, due to the increasing number of students, the traditional blended learning approach does not go far enough to individualization of competencies for students to differentiate on the job market. This is where micro learning courses as enrichment of the blended learning format can be helpful. Micro learning is an approach where teaching contents are structured in short and focused parts (Taylor & Hung 2022), which can be consumed in short time periods (Díaz Redondo et al. 2021). For the completion of a micro learning course, participants obtain so-called micro credentials. These are records of focused learning achievements, that include assessments, meet standards and have standalone value (Beverley 2022). Micro learning courses offer the benefit of personalization. Furthermore, they are competency-based, cost-efficient and flexible, as they are offered in e-learning format (Alamri et al. 2021, Hunt et al. 2020). Thus, micro learning courses foster specialization of students towards certain topics (Ahsan et al. 2023). By embedding micro learning courses into university lectures, for students a holistic learning experience can be created, incorporating the benefits of traditional university lectures, combined with the individualization proposed by an e-learning environment and the personalization proposed by micro learning courses.

3. Method

The aim of this paper is to develop a framework for micro learning courses that clarifies the extent to which micro learning courses can be embedded in ES lectures at university. To create a meaningful and holistic framework, we followed a two-step approach following the implications of Devedžić & Jovanović (2015) for developing micro learning courses. In the first step, we carried out a structured literature review following Webster & Watson (2002) to identify the requirements for the design of micro learning courses in general. We started our literature review with a journal search focusing on leading IS journals complemented by proceedings from major IS conferences. For our database search, we used Web of Science, Science Direct, SCOPUS and AIS eLibrary. We assessed the outlets by their titles, abstracts, and keywords. We performed our iterative keyword search starting with the search string "Micro Learning" AND "Higher Education". We checked title, abstracts and keywords of the identified publications regarding their relevance towards micro learning course design. This step led to 36 relevant publications. Finally, we conducted a backward and forward search (Webster & Watson 2002) which leads to additional 5 relevant results, resulting in 41 relevant hits. To create the framework for embedding micro learning courses in university lectures, we additionally opted for consortium research in a second step to give the implications of literature more value. The consortium research method describes a collaborative exchange of knowledge between practitioners and researchers (Österle & Otto 2010). In our attempt to create valuable extensions to classical lectures we formed our consortium research group containing experienced lecturers of the field of information systems, computer science and business administration, as well as representative students of these study programs. In addition to these, we added experts from practice to the consortium, as it is of importance for micro credential design to not only understand the conceptual part of creation, but also to consider the requirements students towards course design and of potential employers (Ahsan et al. 2023). Thus, we planned a one-day workshop with six lecturers, three students, and three experts. Starting this workshop, we explained our motivation for a new approach towards university lectures and presented the results of our literature review and the resulting requirements. Based on this, the participants of this workshop carried out brainstorming sessions, to identify iteratively further requirements that serve to create an embedded micro learning framework. The literature review resulted in four requirements (R1, R2, R3, R4), and the consortium research method led to a further six requirements (R5, R6, R7, R8, R9, R10), which were to be fulfilled by micro learning courses. These will be examined and considered in more detail in the next chapter when developing the micro learning framework.

4. Development of a Micro Learning Framework

We have developed our micro learning framework based on the ten requirements identified previously. The basis in this framework is the traditional lecture that consists of several theoretical blocks (left part of Figure 1). The contents and proceeding of the lecture itself are not affected by the embedded micro learning courses (right part of Figure 1). When describing the framework, we will use selected publications from the literature review following Cooper (1988).

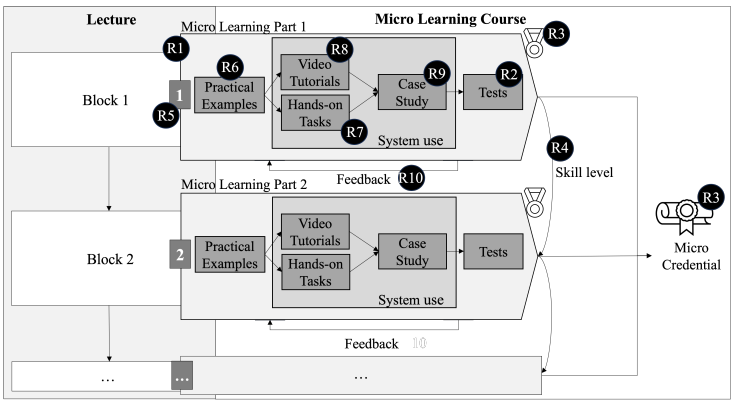


Fig. 1: Micro Learning Framework

Micro learning courses should contain short and focused learning sessions (R1): Micro learning originates from corporate training (Armstrong & Sadler-Smith 2008), where learning is designed "bite-sized" and is embedded in work context, to enable employees learning "just-in-time" (Busse et al., 2020). We transfer this to university context and design short and focused learning bits, that demonstrate the ES use corresponding to lecture content (Díaz Redondo et al. 2021, Taylor & Hung 2022). A micro-learning course consists of several micro learning parts. In our framework, this is demonstrated by each theoretical block being followed by a micro learning part. Each part in turn consists of different bits (e.g., a hands-on task or a video tutorial). *Micro learning parts should include a verification of competency acquisition (R2):* There needs to be an assessment (e.g. tests, or a hands-on task) with which the acquisition of a certain competency can be verified (Lang, 2023). To check whether the students have understood the content of the micro learning part, a test with multiple-choice questions is carried out at the end of each part. *Micro credentials should be awarded to the learner after a verification (R3):* In our framework, after verifying the achievement of a competence (through the assessment), the learner is awarded the micro credential (Fischer et al. 2022) for the specific part. In case the students have accomplished each part of this micro learning course, they will be awarded a micro credential for the entire course. The collection of micro credentials is based on gamification and is designed to motivate students (Sümer & Aydın 2022). *Micro learning courses should cover several competency levels (R4)* (McGreal & Olcott 2022): During the semester, there will be different micro learning parts offered to the students, emphasizing certain topics of the lecture contents, highlighting practical relevant application scenarios. These different micro learning parts mediate different competency level (beginner, intermediate, advanced). Considering the different requirements and competency level of students, there is no need to accomplish all micro learning parts throughout the semester. Nevertheless, to obtain the certification at the end of the semester, all competency-level should be obtained. *Micro learning parts should fit to the content of the lecture (R5):* To enrich the learning experience and to improve learning success, micro learning courses are created, fitting to each or selected blocks of the lecture. These micro credential parts comprise practical examples, which take the contents of the preceding lecture and highlight a topic of certain focus to explain this further to the students. *Micro learning hands-on parts should cover practical relevant content (R6):* In our framework, the practical examples are the introduction to the micro learning parts. They serve as a foundation for the hands-on tasks and the video tutorials, in which students carry out steps in the system to deepen their understanding of this certain topic and to introduce the system use. Typically, an example from practice is presented as a case study, on which the further content of the micro learning part is also based. *Micro learning parts should cover hands-on tasks within the IT system (R7):* A hands-on task can be described

as a specific task on the system, such as creating a business partner in an ES. It was important for all participants in the consortium that the micro-credential covers practical tasks within the system that should be carried out individually. *Micro learning parts should provide guidance on how to carry out the hands-on tasks within the system (R8):* To support the completion of the hands-on tasks and to foster the learning process, it has been stated, that there should be visualized instruction on how to carry out the tasks within the system. These hands-on exercises are accompanied by video-tutorials which explain certain steps and contain background information that will be helpful for students to gain a deeper understanding of the topic and the system. Screencast videos, for example, can be used here. *Micro learning parts should include a case study, which is beneficial for the transfer of learning content (R9):* To emphasize on the work practice, there are connected and guided case studies that build up on the previous elements and encourage students to transfer knowledge to a setting, where the students need to synthesize the competencies learned before and demonstrate that they are able carry out tasks in the system self-contained, by applying these competencies. To check the results of the case study the students will need to make submissions. *Micro learning parts should allow for feedback from the lecturers (R10):* Besides the wish to incorporate self-paced learning elements for attainment of micro credentials, all participants consent, that there should be additional face-to-face meetings for feedback on task-performance and discussion or reflection of results: During the process of the micro credential course, students will receive support and feedback from lecturers. Furthermore, there will be scheduled discussion sessions, where students can exchange on the contents of the micro credentials amongst each other and with the lecturers.

5. Conclusion and Next Steps

In this paper, we highlighted that embedding micro learning content into ES lectures at universities can be a way to provide students with the required competencies for their future employment. Practical competencies in enterprise systems can be taught at an early stage in addition to the traditional university teaching, so that students become specialists in enterprise systems. Despite the advantages, there is a lack of guidance in how to integrate micro learning courses in university lectures. We closed this gap by developing a micro learning framework that can then be used to guide lecturers in universities. Through a literature review and consortium research (Step 1), we were able to identify 10 requirements of micro learning courses (Step 2). On this basis, we developed a micro learning framework (Step 3).

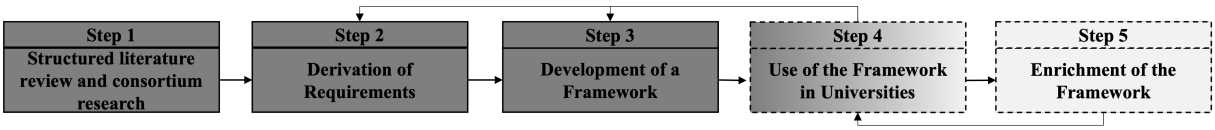


Fig. 2. Research Agenda

We are currently preparing for the developed framework to be used at a private and non-profit university in summer term 2024 and winter term of 2024/25 (Step 4). We have embedded the micro learning content in the summer term in the module "Procurement & Production", which students take in the second bachelor semester of information systems. The module consists of four theoretical blocks, dealing with procurement, requirements analysis, ordering and supplier management. We employ a practical example, video tutorials, hands-on tasks, case studies in the SAP S/4HANA system and tests. We are planning surveys and semi-structured feedback interviews with the lecturer and some student volunteers. We will use the feedback to further improve the framework so that teaching in universities can be meaningfully enhanced by micro

learning content. In the winter term we will repeat this approach in other courses of the curriculum (e.g., financial accounting and controlling). In the future, we will also enrich the existing framework with additional research insights (Step 5). For example, multimedia use in e-learning context is declared as beneficial (Mutlu-Bayraktar et al. 2019). Nevertheless, only providing the contents in multimedia formats does not necessarily lead to better understanding. In neuroscientific research it is claimed that there will only be a positive learning effect, when the media fits the requirements of the task (Huang & Huang 2017). Thus, we are planning for a study in which we will use functional near-infrared spectroscopy to measure the effects of different media formats on learning outcomes. Furthermore, we will investigate the applicability of adaptive environments based on current research such as Haag et al. (2023) and Gherman et al. (2021). In doing so, we will focus on the different levels of knowledge of the students due to the different semesters and on the learning styles of the students. In this context, we will also consider the application of artificial intelligence for fostering individualization of learning (Ruiz-Rojas et al. 2023). With our further research agenda (Figure 2), we want to make an even more significant contribution to the teaching of ES competencies at universities.

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The Impact of Competition-based Learning on the Workplace Learning of Vocational Trainees

Ann-Sophie Conrad (1), Dr. Sebastian Anselmann (2)
(1) University of Mannheim, Mannheim, Germany
(2) University of Education Schwäbisch Gmünd, Schwäbisch Gmünd, Germany

Abstract: In today's strong competition for skilled workers, the vocational training of new employees plays a key role in the future of companies. Where traditional training approaches are increasingly reaching their limits, companies must address the question of how to prepare new and future generations of trainees for more dynamic conditions. Recent studies have shown that the competition-based learning (CBL) approach is a promising tool in this respect. This study investigates the arising question to which extend CBL impacts workplace learning of trainees through a semi-structured literature review. As a theoretical foundation, the 3-P model of workplace learning according to Tynjälä (2013) will be included. Consequently, empirical findings on the effects of CBL will be collected in the literature review and related to Tynjälä's model if effects are present. The final results display a broad applicability of the CBL-concept on multiple professions of vocational trainees in the higher education sector. A modified 3-P model was derived to conclude the collected findings on the effectivity of the CBL approach on the workplace learning of vocational trainees. This adapted 3-P Model can be used to leverage the CBL-method onto multiple vocational training contexts and learning tracks at the workplace that companies steer.

Keywords: Competition-based learning, Workplace Learning, Learning of trainees, New training concepts, Vocational Training

1. Problem Definition and Relevance

The training of new skilled workers is a key tool for companies to ensure a strong workforce. Not only are the competencies that are sought in new employees changing (Barboutidis & Stiakakis, 2023), but also the requirements of the modern workplace (Muzam, 2023). In order to adapt to such changing conditions, new training concepts for learning at the workplace are also constantly needed. Frequently, the concept of Competition-based-Learning has appeared as a new form of learning for trainees. This concept mainly appears in the context of white-collar workers or knowledge-workers (Chan et al., 2020). While there are several studies across some decades (Issa et al., 2014; Johnson et al., 1985) investigating dimensions or models of CBL, there is an ongoing debate on how the effects of competition-based learning effects the concept of workplace learning of vocational trainees. Therefore, this study examines the question of this debate and will follow the research question to what extent Competition-based Learning (CBL) is affecting the workplace learning of vocational trainees. For this purpose, there will be a specifically tailored semi-structured literature review be conducted to collect relevant findings from empirical studies throughout the last two decades. These results can be used for a target specific redesign or addition of the SAP learning frameworks, such as functional, global or even early leadership learning, but especially for the vocational education track of SAP.

2. Theoretical Concepts

Since the semi-structured literature review primary focus on the concepts of workplace learning and the background of competition-based-learning, both concepts will shortly be introduced.

Tynjälä (2013) adapted and expanded the 3-P model to include various approaches that address the demands of an ever-changing world, serving as a foundational framework for workplace learning. In this context, the workplace is situated within a sociocultural environment and is divided into three stages: presage, process, and product. The presage involves factors related to the learner(s), such as learning motivation and prior knowledge, as well as the learning context, including organizational structure and management support. During the process stage, underlying assumptions and self-concepts influence workplace learning, which includes informal, formal, and non-formal learning activities. These activities occur through performing tasks, reflecting on experiences, or tackling new challenges (Tynjälä, 2013, 2022). Finally, the product stage refers to the learning outcomes, such as improved task performance or enhanced workflow.

Referring to Johnson et al. (1985) Competition-Based Learning (CBL) is a methodology where learning occurs through competition, but the learning outcomes are not dependent on the student's score in the competition.

CBL significantly enhances learning processes. To maximize its benefits, teams should be formed in a way that allows members to leverage the collaborative effort inherent in team-based learning (Issa et al., 2014). Specifically, incorporating competitions in games can help maintain students' motivation to study over longer periods. Engaging students actively in the learning process can boost learning efficiency, as they take on active roles (Willard & Duffrin, 2003). This brings active learning to the forefront, with CBL strongly supporting the active learning process. To excel in competitions, students take proactive steps to acquire knowledge ahead of their peers.

The methodology of CBL can be applied across various courses and disciplines (Willard & Duffrin, 2003). Research on CBL has been conducted in numerous fields, digital systems (Perwita et al., 2023), engineering education (Carroll, 2013), mechatronics (Lara-Prieto et al., 2023), nursing education (Alyazeedi & Berry, 2018), business management (Desai et al., 2014).

3. Methodical Approach

This study conducts a semi-structured literature review to investigate competition-based learning (CBL) and its potential impacts on workplace learning among vocational trainees. A semi-structured literature search was chosen as the applicable method, as the aim of this study is to collect studies from a predefined spectrum but does not aim to review all existing relevant literature on the research subjects, since this is a short-term project. According to these aspects, this method corresponds neither to a traditional literature review nor to a structured literature review (Petticrew & Roberts, 2006). However, semi-structured literature reviews have established themselves as a research method for the purposes described (Kojonsaari & Palm, 2023). The focus of the review is to explore and analyze studies centered around the keywords "competition-based learning," specifically those examining the learning process or workplace learning. The search will be conducted via several online sources of large databases for relevant studies, such as Taylor and Francis Online, Wiley Online Library, ScienceDirect or Emerald

Insight. Since the research will be limited to the last two decades, a respective filter for research between 2000 to 2024 will be applied. The objective is to identify and compile the effects observed in empirical studies over time, situating them within the context of workplace learning for vocational trainees. Given the exploratory nature of this research, no hypotheses were predefined. Instead, a research question was articulated during the problem definition. As the concept of competition-based learning is predominantly applied to knowledge workers or white-collar professionals (Chan et al., 2020; Muzam, 2023), the findings of the semi-structured literature review are primarily drawn from studies involving this specific learning population in a vocational context.

4. Empirical Results

The empirical findings will now present the collected insights identified in the reviewed studies. The relationship between the observed effects and Tynjälä's workplace learning model will be examined, and any linkages identified will be contextualized within Tynjälä's theoretical framework. Based on the described methodology, eight studies were selected from the mentioned databases for the literature review, focusing on competition-based learning and its effects on diverse learning groups. These groups span fields such as Computer Science (Cantador & Conde, 2010; Sukiman et al., 2016), Medicine (Maulana et al., 2024), Fashion Design (Chan et al., 2020), Management/Finance (Nor et al., 2022), and Engineering (Gallarta-Sáenz et al., 2023; Paulik & Krishnan, 2001).

4.1. Presage

In Tynjälä's Presage phase, personal and contextual prerequisites are distinguished. Chan et al. (2020) identify Deci and Ryan's Self-Determination Theory as fundamental for learners' actions within the CBL approach, positing that competence, autonomy, and relatedness drive motivation within learners (Deci & Ryan, 2008). Empirical results from Chan et al. (2020) support this, suggesting that the primary personal Presage factor in Tynjälä's 3-P model is the level of self-determination an individual possesses. They also highlight the necessity of intrinsic motivation for voluntary participation in CBL-centered competitions, aligning with the Self-Determination Theory.

Issa et al. (2014) identify eight characteristics of CBL essential for its proper implementation, which correspond to Tynjälä's contextual Presage factors. These characteristics, which are supported by other studies, include group activity (supported by Cantador & Conde, 2010; Nor et al., 2022), learner autonomy and constructivism (supported by Chan et al., 2020), curriculum-based tasks, curriculum-relevant tasks, the design of multidisciplinary and challenging problems (supported by Nor et al., 2022; Paulik & Krishnan, 2001), collective learning results, transparency, and control and monitoring (supported by Cantador & Conde, 2010). These factors collectively ensure the efficacy of the CBL learning environment via then given context of the learners.*Process*

In Tynjälä's 3-P model of workplace learning, the "Process" phase is crucial for learners, encompassing the activities they engage in to achieve learning outcomes. The analyzed studies provide insights into key learning activities that influence the success of the CBL method. Chan et al. (2020) emphasize the importance of professional coaching during the learning process, as it aids learners in understanding case studies and enhances their cognitive and problem-solving activities.

Active engagement with the learning content during task completion is another critical aspect highlighted by Chan et al. (2020). This engagement can lead to the creation of smaller subtasks that help address challenges and correct errors, a finding also supported by Maulana et al. (2024). Paulik & Krishnan (2001) stress the value of peer reviews and constructive feedback, which optimize learner's productivity and continuously improve their solutions. They also note that interpersonal conflicts can arise during long-term CBL tasks, suggesting that conflict resolution management by the instructor is essential. Additionally, appointing a group leader can help structure learning activities and preemptively address conflicts.

Cantador & Conde (2010) highlight the necessity of cooperative interactions among learners to ensure low conflict potential and promote knowledge transfer.*Product*

The analysis of the selected studies differentiates the Product factors in Tynjälä's 3-P model into soft skills (interpersonal competencies) and hard skills (professional, subject-specific competencies). Sukiman et al. (2016) identify seven key soft skills developed through CBL: problem-solving, creative thinking (supported by Maulana et al., 2024), handling competitive situations, a "winner's mindset", time management, teamwork (supported by Gallarta-Sáenz et al., 2023), perseverance, and assertiveness. High learner satisfaction from CBL, as noted by Chan et al. (2020), enhances social competence and collaboration, leading to increased intrinsic motivation and deeper understanding.

CBL also develops hard skills. Chan et al. (2020) highlight improved professional competencies, including technical skills and market knowledge (supported by Gallarta-Sáenz et al., 2023). Maulana et al. (2024) report better overall grades from CBL (supported by Cantador & Conde, 2010), indicating enhanced performance. This performance, often evaluated through subject knowledge, is linked to hard skills. Cantador and Conde (2010) also note an increased ability to learn similar tasks in the future after CBL, representing another hard skill Product factor.

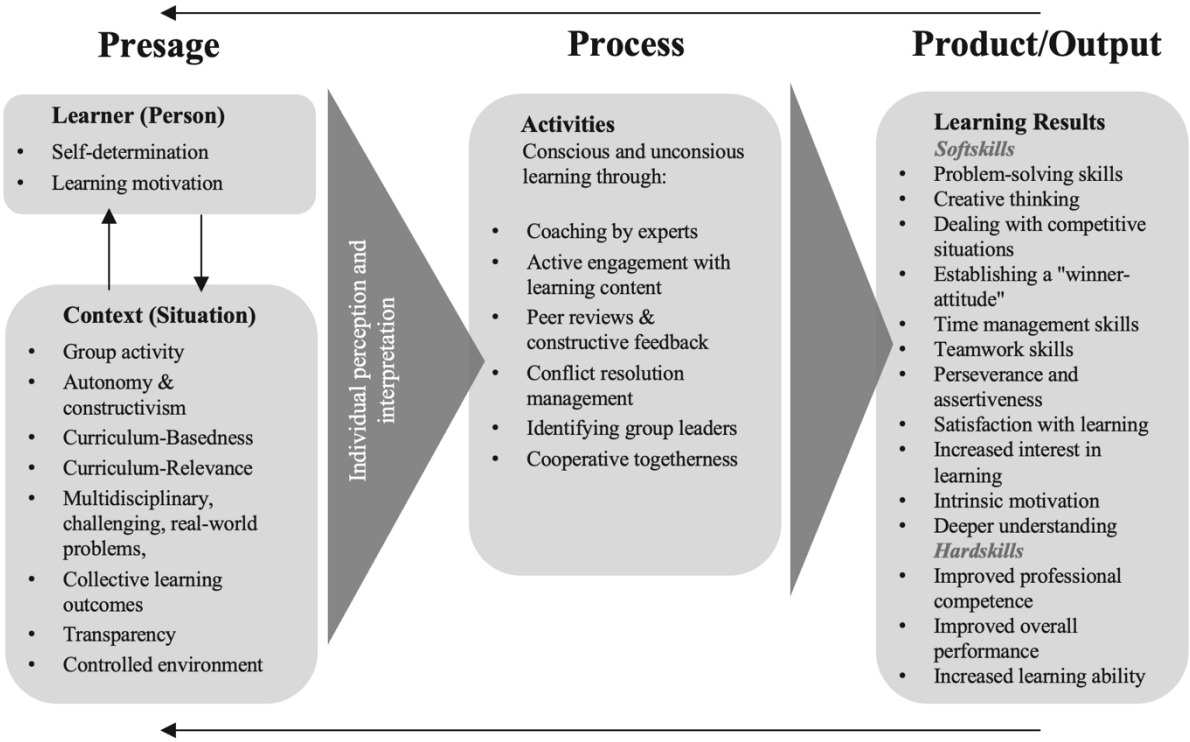

Figure 1. Competition-based Learning in the workplace learning process of vocational trainees, adapted by Tynjälä (2013, 2022)

By integrating the identified linkages and findings, an adapted version of Tynjälä's 3-P Model can be developed to represent the learning process of vocational trainees at the workplace level within a Competition-Based Learning (CBL) framework. This refined model, displayed in Figure 1 encapsulates the learning dynamics of vocational trainees in a CBL context, offering an operationalized perspective on applying the CBL approach to vocational training programs within organizational settings.

5. Discussion

This literature review aimed to examine Competition-Based Learning (CBL) and its potential effects on workplace learning for vocational trainees. Findings from eight predominantly empirical studies were integrated into Tynjälä's (2013; 2022) 3-P model to understand the learning process at the workplace**.** Key findings highlighted several factors within the 3-P model. Firstly, **presage** factors were identified, including both personal and contextual elements. Personal factors such as *self-determination* and *learning motivation*, as identified by Chan et al. (2020) and rooted in the work of Deci & Ryan (2000; 2008), play a crucial role. Contextual factors, derived from Issa et al. (2014), emphasize the importance of *group activity* (supported by Cantador & Conde, 2010; Nor et al., 2022), *learner autonomy and constructivism* (supported by Chan et al., 2020), *curriculum-based tasks*, *curriculum-relevant tasks*, the design of *multidisciplinary and challenging problems* (supported by Nor et al., 2022; Paulik & Krishnan, 2001), *collective learning results*, *transparency*, and *control and monitoring*.

In terms of **process** factors, effective learning activities were described through *expert coaching*, *active engagement with learning materials* (Chan et al., 2020; Maulana et al., 2024), *peer reviews*, and *constructive feedback* (Paulik & Krishnan, 2001). Additionally, well-

structured *conflict resolution management*, gro*up leadership identification*, and *cooperative interaction* within the CBL framework were emphasized (Cantador & Conde, 2010).

Regarding **product** factors, the analysis identified two primary areas: soft skills and hard skills. Soft skills include *problem-solving*, *creative thinking*, *competitive skills*, *a "winner mentality"*, *time management*, *teamwork*, *perseverance*, and *assertiveness* (Gallarta-Sáenz et al., 2023; Maulana et al., 2024; Sukiman et al., 2016). *High learner satisfaction* from CBL (Chan et al., 2020) enhances social competence and collaboration, leading to increased *interest in learning*, *intrinsic motivation* and *deeper understanding*. Hard skills encompass *improved professional competence*, such as increased expertise or market understanding (Chan et al., 2020), *better overall grades* (Cantador & Conde, 2010; Maulana et al., 2024) and *enhanced learning capacity* post-CBL (Cantador & Conde, 2010).

The findings were synthesized into Tynjälä's (2013; 2022) 3-P model, demonstrating the positive effects of CBL on workplace learning for trainees. The research validates Tynjälä's model by clearly aligning study findings with the 3-P factors, particularly the link between presage and product factors via learning motivation.

However, the study has several limitations. The focus predominantly on higher education limits the generalizability of the results to vocational training and lower education sectors. Additionally, the effectiveness of CBL appears contingent on high intrinsic motivation, which is more prevalent in higher education contexts. There are also potential negative impacts of competition, such as ego damage and dysfunctional coping strategies, as noted by Gallarta-Sáenz et al. (2023), and Paulik & Krishnan (2001). Furthermore, the lack of direct comparisons with other learning methods, such as Problem-Based Learning, restricts conclusions on the relative effectiveness of CBL. The methodology of a semi-structured literature review may be limited by subjective study selection, restricted database access, variability in study quality, and heterogeneity in research designs and outcomes. Additionally, the short research timeframe as this is no long-term research project may constraint the validity and reliability of the review's conclusions.

To optimize the implementation of Competition-Based Learning (CBL) for apprentices, this study presents several practical and research-oriented recommendations. Practically, companies, such as SAP should conduct pilot projects in vocational and lower-education sectors to evaluate the effectiveness and transferability of CBL to these specific learning groups. These pilot projects should emphasize competencies critical for vocational professions. Additionally, offering apprentices a variety of learning methods is advisable. Based on Baldwin et al. (1991), learners should have options to choose from, either from multiple CBL programs or other learning methods, facilitating diverse learning opportunities both within and outside the CBL framework. Furthermore, companies should implement professional performance assessment and measurement systems to gauge the training transfer and learning success of CBL programs, aiding in the management and improvement of training concepts (Littlejohn, 2022). Such systems enable informed decisions on the development and adaptation of learning methods. Furthermore this study and the modified 3-P-Model can be adapted by companies to enable their vocational trainees for several real-life work situations. This framework could be of strategic interest for companies to implement into their personnel development strategy and following learning concept toolbox. Precise recommendations would include to adapt the CBL-framework to different learning tracks for the trainees. Competition could therefore be enhanced to educate in a functional sector, but also for developing personnel competencies in a more general learning approach. By training vocational trainees in early leadership skills with

the CBL-approach, future-oriented and resilient junior-managers could evolve out of this approach. CBL can therefore be applied to all learning frameworks companies offer, as this method has been proven to enrich the training transfer of several professions during this discussion.

For research, several essential recommendations arise. Future empirical studies should focus on examining the application of CBL in vocational professions and lower-education sectors to verify the transferability of existing findings to these contexts. This highlights a clear research gap, as few studies have addressed CBL in vocational or lower-education settings. Additionally, comparative studies between different learning concepts, such as Problem-Based Learning (PBL) and CBL, are necessary to understand the relative advantages and disadvantages of each approach, providing a basis for practical recommendations. Another critical research area should investigate the long-term effects of CBL on the professional development and career trajectories of apprentices. It is important to analyze how CBL influences the development of technical and social competencies, as well as job satisfaction and performance over time. Moreover, future studies should explore the social dynamics within the CBL context, including how competition affects the work environment, collaboration, and interpersonal relationships in training settings. A detailed analysis of these social dynamics could offer valuable insights into optimizing CBL to foster a positive learning environment.

In conclusion, CBL shows promising effects on workplace learning processes of vocational trainees. However, a nuanced approach is necessary to tailor CBL to the specific needs and conditions of various educational sectors and learner groups. Implementing these recommendations could lead to significant advancements and insights in both practice and research regarding workplace learning for apprentices.

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Teaching Business Process Simulation and Sustainability in Procurement

H. Sperling
SAP SE, Walldorf, Germany

Abstract: With increasing relevance of business process management (BPM) in practice, BPM and process mining have become integral parts of academic curricula in many fields of study. However, despite increasing demand for teaching content leveraging data and analytics, business process simulation has received relatively little attention. Using a design science approach, we develop and evaluate a process simulation curriculum on sustainability in procurement that enhances data-driven process optimization skills and conveys real-life business process knowledge. We validate the included process models with SAP practitioners and an academic expert on procurement. Moreover, we apply the teaching cases in an educational session on SAP Signavio Process Transformation Suite, academic edition, and evaluate the curriculum. With our study, we add to existing research on SAP academic education and contribute to the wider BPM academic community.

Keywords: BPM, sustainability, simulation, optimization, transformation.

1. Introduction

Business process management (BPM) software is essential in meeting the demands of today's fast-paced business environment. Modern BPM platforms include a range of capabilities such as process modeling, process mining, automation, and simulation (Dumas et al. 2018). While process modeling and mining techniques have recently gained in popularity, business process simulation (BPS) offers untapped potential for industry practice as well as academic teaching. Simulation technologies have long played a pivotal role in numerous domains, ranging from digital twins to business scenarios or climate models. By creating and analyzing "what-if" business scenarios (López-Pintado & Dumas 2022), BPS can serve as a crucial tool for organizations seeking to optimize their business operations and enhance process efficiency. Analysts may address questions about business process cycle and waiting times, gaining valuable insights into potential improvements and bottlenecks to refine strategies and achieve optimal performance (Chapela-Campa et al. 2023). For lecturers seeking to convey a thorough understanding of business processes and enhance their students' data-driven reasoning skills, BPS stands out as a valuable tool that effectively conveys important insights about efficient and sustainable business practices.

2. Conceptual Background

2.1. BPM and Process Simulation

BPM is a management discipline based on the cross-organizational analysis, design, and implementation of processes (Rosemann & vom Brocke 2015). Analogously, BPM software helps coordinate the behavior of people, systems and devices in business processes to produce certain outcomes (Gartner 2024). Business Process Model and Notation standard (BPMN) has become a widely adopted convention for business process modeling, used by practitioners and

academics alike (Dumas et al. 2018). Maintained by the Object Management Group (Object Management Group 2024), the International Standards Organization released BPMN 2.0 as a standard in 2013 (ISO 2013).

Akin to leveraging so-called digital twins for tasks like efficient maintenance and component design in manufacturing and robotics (Phanden et al. 2021), process simulation capabilities of BPM software can help identify inefficiencies and bottlenecks in existing processes and provide clues for improvement (SAP Signavio 2024c). As a technique to analyze "what-if" scenarios, BPS bases on business process models that include parameters capturing available resources, e.g., in terms of capacity, processing times, or costs (López-Pintado & Dumas 2022).

The SAP Signavio Process Transformation Suite is an integrated platform for business process management and related capabilities (SAP Signavio 2024a). Offering a subset of the commercial BPM platform, the SAP Process Transformation Suite, academic edition (SAP Signavio 2024b), grants students, professors and lecturers free access of the SAP Signavio Process Manager. It includes a comprehensive suite of tools for designing, visualizing, and documenting business processes. Complementing these process modeling capabilities, the software's BPS capabilities allow professors, lecturers and students to simulate and analyze business processes in a dynamic virtual environment. By simulating different scenarios, researchers and practitioners can evaluate the impact of changes, optimize resource allocation, and identify opportunities for improvement.

2.2. Current BPM Education

With rising popularity of academic disciplines such as Computer Science, Information Systems, or Information Technology in conjunction with Business courses, educators have long realized the need for experienced BPM lecturers and teaching resources for BPM academic education (Moormann & Wasana 2012). Although elements of the discipline have been established since approximately 100 years, academic curricula have only started incorporating BPM education in the last decades (Koch et al. 2022). BPMN and other business process modeling conventions are nowadays frequently taught as a part of Business Administration and Business Informatics (i.e., Business and Software Engineering) academic degrees (Koch et al. 2022). In this context, process mining has emerged as an important teaching component in BPM curricula and educational data mining (Hicheur Cairns et al. 2015), addressing the need for data-driven education.

Evaluations of past process modeling lectures revealed that hands-on exercise sessions of BPMN and related conventions resulted in significantly higher motivation and knowledge retention of students. However, despite the increased engagement resulting from hands-on modeling activities, we received some constructive feedback suggesting a need for more data-driven tools and a desire for more complexity. In addition to process modeling capabilities, students would benefit from gaining insights into process performance, practicing scenario analysis, and supporting decision-making with hands-on exercises and system access. A case study that integrates process modeling with BPS is likely to be the most effective teaching method and achieve the highest level of student engagement.

3. Simulation Case Development

3.1. Method

Since a business process model alongside process capacity parameters forms the basis for BPS (López-Pintado & Dumas 2022), we focus on the design of BPMN models to form the main building blocks of our teaching case for process simulation. To develop these technical artifacts as well as a didactic teaching concept, we followed an iterative research approach broadly based on the components of design science research (Gregor & Jones 2007). This research methodology allows us to take on the necessary socio-technical perspective for BPM curriculum design and guides our case development in a real-world educational context (Hevner et al. 2004). As opposed to describing and evaluating artifact *implementation* common in design science projects (Gregor & Hevner 2013), i.e., the implementation of our BPMN models in practice, we describe artifact *application* in the educational setting and evaluate the suitability of our simulation case study for BPM education. The following paragraph describes the first two design science components as laid out by Gregor & Jones (2007) as well as the requirements for development and evaluation. The next section provides a "blueprint" of the developed process models to define principles of form and function, followed by description of our case study's real-life application in the teaching context, i.e., expository artifact instantiation (Gregor & Jones 2007). We conclude with an evaluation of BPMN artifacts and corresponding teaching case to lastly discuss benefits and limitations.

3.2. Scope, Concepts and Requirements

The purpose and scope of this study is to develop a BPM case study that can be used to effectively convey data-driven process optimization skills alongside real-life business process knowledge. In this context, the industry standard BPMN 2.0 detailing the rules and conventions for process modeling in practice represents the main construct for the development of design principles and artifacts. Motivated by the benefits of computer- and technology-assisted learning (Giroire et al. 2006), our didactic approach is based on the concept of interactivity. By leveraging the simulation capabilities of the SAP Signavio Process Transformation Suite, academic edition, we seek to develop a BPM curriculum that

- engages students and motivates learning through an interactive format
- conveys business process knowledge as well as analytical skills
- is adaptable in length and complexity to different course specifications.

4. Simulation Teaching Case

Sustainability remains a crucial topic for the younger generations (Pew Research Center 2021). Therefore, the newly introduced Sustainability Due Diligence Directive by the European Union (EU) mandating corporate sustainability due diligence (European Commission 2022) serves as an excellent starting point for our teaching case narrative. The scenario presents an ideal example for procurement process improvement by combining regulatory requirements–and thus potential business drawbacks–with purposeful sustainability practices in business operations.

The procure-to-pay (P2P) process is the subject of existing simulation enablement exercises and thus presents a good starting point to achieve sustainable supply chain practices. Existing SAP enablement material for process optimization using BPS focuses on the purchasing process, visualizing the efficiency gains resulting from the implementation of an ERP system due to automated purchase order creation and purchasing group assignment. To allow lecturers to flexibly adjust the duration and depth of BPM instruction, it is sensible to embed new teaching material into the existing enablement content. Starting from the P2P process, we thus integrate our supplier selection process as a sub-process to connect both simulation teaching cases. To create an engaging learning experience, we design a case study setting centering around *A Company that Makes Apparel* (ACM Apparel). ACM Apparel designs and prints t-shirts, dresses, pants and other clothing items for resale, mostly through European business partners. It is based in Frankfurt, Germany, and employs over 1.000 employees. Starting point of the first exercise is the process description of a manual supplier selection process, distributing requests for proposals (RFP) and soliciting offers via e-mail or post. Fig. 1 provides the solution blueprint of the base modeling exercise in BPMN 2.0, alongside the textual process description.

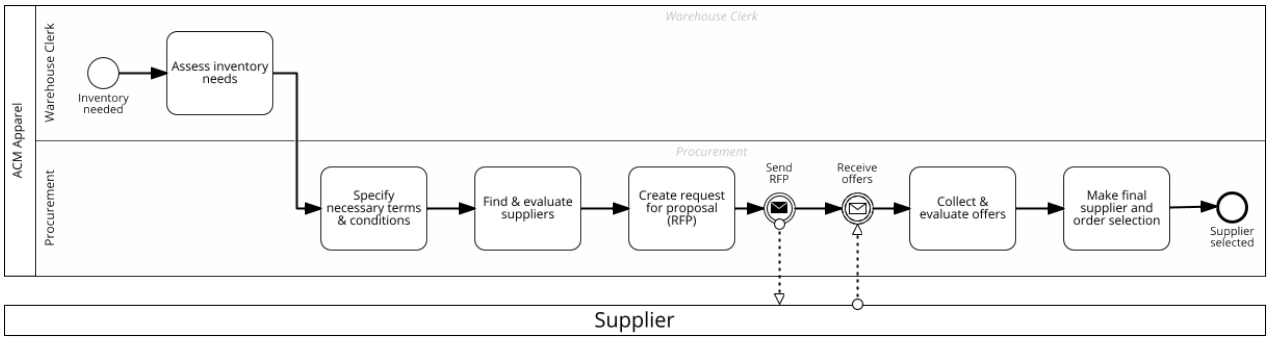

Fig. 1: BPMN 2.0 model for the manual sub-process of ACM Apparel's supplier selection. Process description: After the Warehouse Clerk assessed inventory needs, the Procurement department specifies the necessary terms and conditions for purchase of new inventory. Afterward, the Procurement department has to find potential suppliers (e.g., through web-based search and internal contacts) and evaluate them. After creating a so-called request for proposal (RFP), the Procurement department solicits offers by a number of suppliers. Procurement collects and evaluates the offers to then make a final supplier and order selection. The final selection of a supplier and respective order concludes the process.

4.1. Supplier Selection and Supply Chain Act

In the scenario section of the simulation interface, a cost of 10€ covers printing and postage costs in activity *Collect & evaluate offers*, which happens after 4 hours of waiting time to be adjusted in the duration tab. Additional duration parameters apply (Tab. 1), while duration of 20 executions and capacity at a 40-hour work week at hourly costs of 50€ remain unchanged. Running the manual supplier selection simulation with base parameters results in overall costs of 1.748.33€ and 18 out of 20 process executions completed.

To introduce the topic of sustainability, the case study now introduces the EU's Sustainability Due Diligence Directive (or so-called supply chain act). Subject to employee number and revenue thresholds, the law makes sustainability due diligence in procurement mandatory for all companies headquartered in Europe or operating in Europe, covering an estimated 16.800 companies worldwide (European Commission 2022). At this point in the teaching case, lecturers are encouraged to address the students directly, engaging in a discussion about labor rights and global warming in business operations. Asking participants to brainstorm about the retail industry in particular, the discussion may result in ideas and recommendations such as

enforcing safe labor standards and strictly eliminating child labor, using sustainable materials (e.g., organic cotton), or limiting transport emissions in sourcing.

Tab. 1: Durations of tasks in base and sustainability models of the supplier selection process.

Task	Base model	Sustainability model
1. Assess inventory needs	10 minutes	10 minutes
2. Specify necessary terms & conditions	30 minutes	1 hour
3. Find & evaluate suppliers	10 minutes	10 minutes
4. Create request for proposal (RFP)	30 minutes	1 hour
5. Collect & evaluate offers	10 minutes	10 minutes
6. Make final supplier and order selection	5 minutes	5 minutes
Intermediate Message Event: Receive offers	4 hours	4 hours

Increased sustainability due diligence requirements require additional bureaucracy. Consequently, the next step in the case study includes an increase of activity durations in the manual supplier selection process (Tab. 1). Saving the newly created sustainability scenario and re-running the manual supplier selection simulation results in increased total costs of 2.174,17€ and a significant bottleneck. Mainly due to RFP waiting times and the resulting bottleneck in the *Procurement* department, only a single case out of 20 total cases is completed.

4.2. Sustainability and Automation

To resolve the bottleneck in *Procurement* and decrease costs while ensuring sustainability due diligence, ACM Apparel re-engineers the supplier selection process. Process steps 2-5 can be executed with the help of an IT system, in this case SAP Ariba for procurement. Moreover, combining this set-up with SAP Business Network, process steps 3-4 can be digitized and automated. As a result, offer evaluation and comparison no longer incurs extra cost, and task duration of process steps 1-5 decreases to 10 minutes each.

In addition to decreasing process duration and cost, the big advantage of this improved supplier selection process lies in sustainability compliance by increasing supplier self-reporting and transparency as well as allowing for an integration of external sustainability metrics (e.g., supplier sustainability certificates) into the selection process. Fig. 2 illustrates the optimized supplier selection process. The optimized supplier selection process results in significantly reduced costs of 416,67€ while completing all cases.

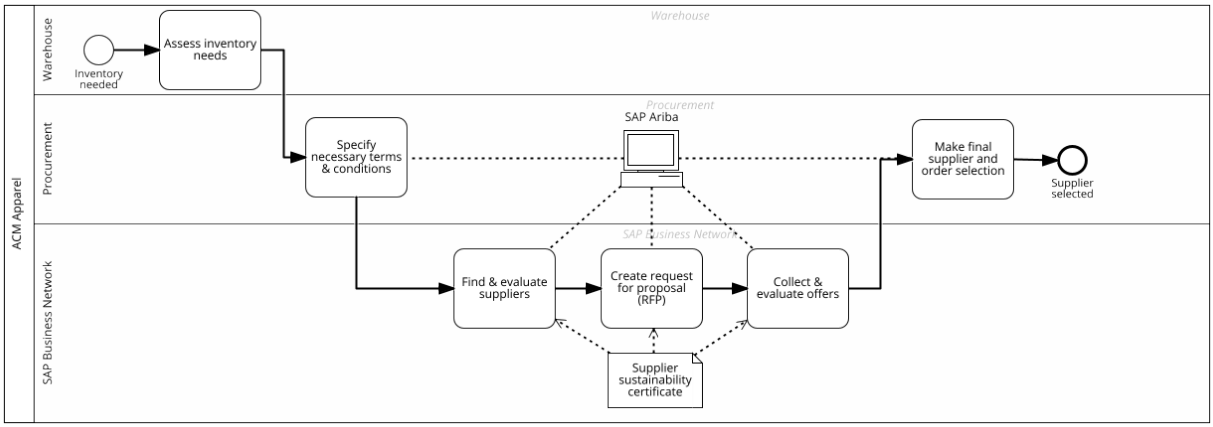

Fig. 2: BPMN 2.0 model of the optimized supplier selection process including SAP Ariba & SAP Business Network.

5. Application and Evaluation

We validated both BPMN models with industry practitioners as well as a procurement researcher to ensure correctness and completeness of the simplified process depictions. Moreover, we presented the case at the SAP Community Conference Central Asia and Caucus 2024 in Almaty, Kazakhstan. Six SAP lecturers took part in our BPS case with SAP Signavio, academic edition, as part of a 90-minute session, which helped to estimate time needed for the developed teaching case.

Evaluating the design of our developed simulation teaching case study with practitioners and validating it in educational practice ensured suitability of our design for BPM teaching. First, our case narrative has the potential to excite students and motivate their learning by centering on the highly relevant topic of sustainability in the context of a procurement process example. Second, the use of SAP Signavio Process Manager, academic edition, ensures interactive teaching and hands-on participation of learners. By familiarizing participants with procurement processes and specific concepts such as RFP in sourcing, they gain insights into real-world process execution. Moreover, by developing process models in BPMN 2.0 and simulating those with dynamic parameters, we convey tangible BPM knowledge and foster analytical skill development as well as abstract thinking. Third, our teaching case is mutable (Gregor & Jones 2007) in the sense that incorporation into the broader context of P2P processes and existing SAP Signavio simulation learning content is possible. Moreover, lecturers may flexibly adjust the length and difficulty of conveyed BPM content. On the one hand, they may demonstrate modeling and simulation and have students repeat their work. On the one hand, they may choose to have learners solve the exercises by themselves or as part of a group to then present their respective solutions in plenum.

6. Conclusion

We have designed, applied, and evaluated a teaching case for BPS using SAP Signavio Process Manager, academic edition, that can be used to effectively convey data-driven process optimization skills alongside real-life business process knowledge. To the best of our knowledge, comparably little openly available teaching content exists in the realm of BPS. We add to existing work on BPM education by developing a case study on teaching sustainability

in procurement that can be flexibly adjusted to fit a variety of classroom scenarios and educational settings. By publishing our content for active classroom use, we hope to contribute to SAP lecturer's work and the BPM academic community alike.

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Greifbare Mathematik - Mathematische Bildung durch Programmierung und Stickerei

Jadga Hügle
SAP SE

Abstract: Mathematik als Unterrichtsfach haftet sowohl in der Hochschullehre als auch in der schulischen Bildung häufig ein Nimbus von Weltfremdheit an. In einem gemeinsamen Projekt von SAP und dem African Institute for Mathematical Sciences (AIMS) versuchen wir daher Mathematik, insbesondere Geometrie, für Schüler:innen in der Sekundarstufe über die Programmierung von Stickmustern zu vermitteln. Mit geometrischen Mustern bedruckte und bestickte Stoffe spielen in vielen afrikanischen Kulturen eine große kulturelle, modische und auch wirtschaftliche Rolle. Durch das Recoding klassischer Stoff-Designs lernen die Schüler:innen die sogenannte Problem-Decomposition, also ein Problem in kleinere, leichter umsetzbare Einheiten aufzuteilen, die eine wichtige Rolle beim Computational Thinking spielt. Die unterschiedliche Komplexität der Muster bietet eine große Chance zur Binnendifferenzierung und sorgt dafür, dass alle Schüler:innen ein optisch ansprechendes Ergebnis erzeugen können. Der kulturelle Lebensweltbezug und die Erstellung ansprechender Designs stehen im Vordergrund und die Mathematik wird eher als Mittel zum Zweck betrachtet. So wird beispielsweise die Formel für die Länge einer Kreissehne nützlich, wenn man damit die Länge eines allgemein formulierten Blütenblatts aus zwei gegenüberliegenden Kreisbögen berechnen kann. Die Umsetzung eigener Designs auf der Stickmaschine verbindet individuelle Expression positiv mit Mathematik. Die Übertragung von Software in die echte Welt ermöglicht es, das Erlernte wortwörtlich in die eigene Community zurückzutragen und wirkt sich unterstützend auf die Selbstwirksamkeit der Schüler:innen aus.

In dieser Community Session möchten wir Erfahrungen aus der Umsetzung und Best Practices aus dem Projekt zeigen und die Übertragbarkeit des Projekts auf andere Bereiche erörtern. Zudem möchten wir versuchen, generelle Schlüsse auf die innovative Vermittlung von als schwierig geltenden Themen zu ziehen.

Erfolgsfaktoren für die didaktische Gestaltung eines Fallbeispiels für SAP S/4 HANA FI/CO

FH-Prof. Mag. DI Peter Hofer & Sara Oberleitner, BA, MA
Fachhochschule Oberösterreich, Fakultät für Wirtschaft und Management, Steyr, Österreich

Abstract: Die Digitalisierung hat in den letzten Jahren den Finanzbereich signifikant verändert. SAP S/4 HANA hat sich hierbei als Kernkompetenz im externen und internen Rechnungswesen etabliert. Neben dem hohen Nutzungsgrad in der Wirtschaft entwickelte sich SAP auch in der Lehre zu einem integralen Bestandteil. Trotz didaktischer Gestaltungsempfehlungen zur allgemeinen Lehre wurden spezifische Erfolgsfaktoren zur SAP-Online-Lehre noch nicht erforscht. Dieser Beitrag fokussiert daher auf die Analyse von generellen didaktischen Erfolgsfaktoren auf Basis einer systematischen Literaturrecherche, welche die Grundlage für die empirische Untersuchung von spezifischen Faktoren für die SAP-Online-Lehre bilden. Die von der SAP University Alliance angebotene CO-Fallstudie wurde mit diesen Erfolgsfaktoren modifiziert. Die Analyse in einem Experiment mit Studierenden des Bachelorstudiengangs Controlling, Rechnungswesen und Finanzmanagement konzentrierte sich auf den Vergleich der Effizienz und Effektivität der beiden Fallstudien und analysierte zusätzlich die Integration der Erfolgsfaktoren. Die Benutzerfreundlichkeit der Fallstudie wurde insbesondere durch die Verwendung von Lernvideos signifikant erhöht. Die Effektivität konnte durch die Wiederholung von Textelementen und einer überarbeiteten Visualisierung, die Effizienz durch die Hervorhebung von Zusammenhängen und die Generierung von leichtem Stress zusätzlich verbessert werden. Ein zukünftiges SAP-Lehrangebot sollte sich daher durch die durchgängige Integration dieser empirisch bestätigten didaktischen Erfolgsfaktoren auszeichnen und mit benutzerfreundlichen Fallstudien einen höheren Lernerfolg erzielen.

Keywords: Online-Lehre, SAP S/4 HANA, SAP-Fallbeispiel, Didaktik, Benutzerfreundlichkeit

1. Einleitung

Das Umfeld von Unternehmen wurde von Megatrends wie Digitalisierung und Industrie 4.0 verändert (Alcácer und Cruz-Machado 2019, S. 900). Diese Änderungen in der Unternehmensführung und -steuerung werden, wie Studien demonstrieren, notwendigerweise von einer integrierten Informationsbasis in Form von Enterprise Ressource Planning (ERP)-Systemen vorangetrieben (Dahal 2019, S. 5). Hierbei werden speziell Kenntnisse der ERP-Software SAP von den zukünftigen Controllern und Controllerinnen gefordert (Oesterreich et al. 2019, S. 15). Aufgrund seiner Positionierung am Softwaremarkt stellt SAP eine geeignete Lösung dar, um in das Curriculum von Universitäten bzw. Fachhochschulen integriert zu werden (Blount et al. 2016, S. 186). Allerdings zeigen sich neben Chancen für die Studierenden auch Herausforderungen bei der Integration von SAP in das Curriculum, welche speziell für die Online-Lehre gelten (Andera et al. 2008, S. 607).

Die Didaktik ist in ihrer Forschung geprägt von einer Vielzahl an Empfehlungen, wie z.B. die didaktische Reduktion (Lehner 2019, S. 124–126). Insbesondere für den SAP-Unterricht unter Einbeziehung von Fallstudienansätzen, gibt es allerdings keine expliziten Empfehlungen (Soellner 2021, S. 119–121). In diesem Paper sollte der Schwerpunkt daher auf didaktische

Erfolgsfaktoren gelegt werden, wodurch eine verbesserte Lehre im SAP-S/4 HANA-Bereich ermöglicht werden soll (Freeman et al. 2014). Deren Analyse, speziell für die Online-Lehre ist essenziell, um das Wissen langfristig in die Unternehmenspraxis transferieren zu können.

2. Zielsetzung und Forschungsfragen

Zielgruppe dieses Beitrags bilden Unternehmen, Lehrende und Lernende, welche die SAP-ERP-Technologie nutzen. Die Zielsetzung besteht einerseits in einer Erleichterung und gesteigerter Anwendungsfreundlichkeit der SAP-Lehre, andererseits auch in einem leichterem Zugang und einer einfacheren Gestaltung der aktuellen SAP-Version S/4 HANA für die Lernenden.

Der empirische Teil des Beitrags untersucht auf Basis einer Fallstudie der SAP University Alliances (SAP UA) die Erfolgsfaktoren für die Gestaltung eines didaktischen Lehrkonzepts für SAP S/4 HANA, um Empfehlungen für den SAP-Lehrbetrieb abgeben zu können.

Die folgenden Haupt- und Subforschungsfragen werden aus der Zielsetzung abgeleitet:

Was sind die Erfolgsfaktoren für die Gestaltung eines didaktischen Fallbeispiels im Hinblick auf SAP S/4 HANA CO für die Lehre im Finanzbereich?

- Welche didaktischen Erfolgsfaktoren sollten bei der Planung eines Fallbeispiels berücksichtigt werden?
- Wie lässt sich ein anhand der aus der Literatur abgeleiteten Erfolgsfaktoren optimiertes SAP S/4 HANA-Fallbeispiel gestalten?
- Lässt sich ein signifikanter Unterschied des Lernerfolgs durch die Anwendung der abgeleiteten Erfolgsfaktoren auf das SAP-Fallbeispiel feststellen?
- Welche Implikationen ergeben sich daraus für die SAP-Lehre?

3. Online-Didaktik

3.1. Erkenntnisse aus der Didaktik

Auf Grundlage der Literaturrecherche zu Lernen und Gestaltung der Lehre werden die folgenden wesentlichen didaktischen Faktoren für eine erfolgreiche Lehre zusammengefasst:

> *(1) Freie Erarbeitung und aktives Lernen* (2) *Spiel und Simulation* (3) *Wiederholung und Übungen* (4) *Visualisieren* (5) *Strukturierung (6) Mit Vorwissen verknüpfen* (7) I*nhalte im Kontext* (8) *Beziehungen zwischen Teilelementen* (9) *Zielklarheit (10) Stoffreduktion, Inhaltsreduktion* (11) *Leichter Stress* (12) *Übermittlung über mehrere Eingangskanäle* (Freeman et al. 2014; Herrmann 2009; Kron et al. 2014; Lehner 2019; Michael 2006; Schilling 2016)

3.2. SAP- Lehrkonzepte und didaktische Herausforderungen in der Online-Lehre

Die eigenständige Anwendung ist für einen nachhaltigen Anstieg der Motivation der Lernenden wesentlich, welche in der SAP-Lehre durch einen in die SAP-Geschäftsprozesse integrierten Fallstudienansatz ermöglicht wird. Eine benutzerfreundliche Gestaltung des Fallbeispiels ist für den Lernerfolg essenziell, welche von den Lehrerenden hohe Fähigkeiten erfordert. Zusätzlich

ist eine gelungene Einführung der Lehrkraft in die Aufgaben der Fallstudie relevant, welche mit einem Handlungsleitfaden zur Vorstellung der Prozessschritte gewährleistet werden kann. (Baumeister et al. 2010, S. 1672–1673; Winkelmann et al. 2010, S. 1627; Singh 2016, S. 28–29)

Der Großteil der verfügbaren Fallbeispiele basiert auf Online-Lehrmaterialien der SAP SE. Vor ihrem Lehreinsatz werden diese Materialien überarbeitet und an das jeweilige Lehrkonzept angepasst (Herzwurm et al. 2010, S. 1658; Winkelmann et al. 2012, S. 3–5). Die größten Herausforderungen beim Einsatz der SAP-Materialen stellt vor allem die Komplexität des Systems, die Benutzeroberfläche von SAP, die praktische Anwendung und Erfahrung und der hohe Zeitaufwand für die Entwicklung der Unterrichtsmaterialien dar (Baumeister et al. 2010, S. 1674–1676; Winkelmann et al. 2010, S. 1631–1633). Die Lernenden sollten sich nicht nur auf die Durchführung der Übungen konzentrieren, sondern zum Verständnis der Aufgaben hingeführt werden. Für SAP-Neulinge sollte vorab eine Einführung zur Nutzung des Systems angeboten werden (Blount et al. 2016, S. 194–198; Davis und Comeau 2004, S. 7–8), Lernende mit Vorkenntnissen sollten zusätzlich an anspruchsvollen Szenarien arbeiten können (Winkelmann et al. 2010, S. 8; Herzwurm et al. 2010, S. 1658).

4. Empirie

4.1. Studiendesign

Im ersten Schritt werden die relevanten didaktischen Erfolgsfaktoren für die Lehre aufgrund der Erkenntnisse aus der Literatur definiert. In der empirischen Untersuchung wird ein bereits bestehendes Fallbeispiel der SAP UA für S/4 HANA CO *(Fallbeispiel A: Original)* mit diesen Erfolgsfaktoren verglichen. Die bestehende Fallstudie basiert auf dem Modellunternehmen Global Bike, das speziell für die SAP-Lehre entwickelt wurde (Hug und Poscheschnik 2020, S. 89–91; SAP University Alliances 2019). Nach der Erstanalyse werden die Erfolgsfaktoren auf die Global Bike-Fallstudie zur Entwicklung einer verbesserten Version *(Fallbeispiel B: Adaptiert)* angewendet. Einzelne Aufgabensequenzen aus beiden Versionen werden anschließend von Studierenden aus dem Finanzbereich in der Oberfläche SAP-Fiori gelöst.

Für das Experiment wird die Methodik der Randomisierung und der Verblindung durchgeführt. Die Kontrollgruppe verwendet das originale SAP-Fallbeispiel und die Versuchsgruppe die verbesserte Version. Die Studie wird in Microsoft Teams durchgeführt, um vom Experiment Audio-, Video- und Bildschirmaufnahmen zu machen. Während des Experiments werden Beobachtung, Think-Aloud-Protokoll und schriftliche Befragung als Erhebungsmethoden verwendet (Döring und Bortz 2016, S. 707; Hug und Poscheschnik 2020, S. 76–77).

Im Rahmen des Experiments wurden die Effektivität (Richtigkeit der Lösung) und die Effizienz (Dauer der Aufgabenlösung) der einzelnen Aufgaben gemessen und mittels deskriptiver und schließender Statistik ausgewertet und auf signifikante Unterschiede analysiert. Die transkribierten Befragungen und Think-Aloud-Protokolle werden mit qualitativer Inhaltsanalyse nach Mayring (1991) ausgewertet.

Die Zielgruppe für diese Studie bilden Studierende aus dem Finanzbereich, die keinerlei SAP-Kenntnisse besitzen, aber Grundkenntnisse der Kostenrechnung aufweisen. Hierfür werden Studierende des Bachelorstudiengangs Controlling, Rechnungswesen und Finanzmanagement (CRF) der FH Oberösterreich ausgewählt. 21 CRF-Studierende mit annähernd gleicher

Geschlechterverteilung (w = 57,14%, m = 42,86%) und Aufteilung auf Vollzeitstudierende und berufsbegleitend Studierende (VZ = 52,38%, BB = 47,62%) nahmen am Experiment teil.

4.2. Hypothesen

Nachfolgende Hypothesen werden für die Veränderung der Benutzerfreundlichkeit durch die Anwendung der didaktischen Erfolgsfaktoren in der adaptierten Version B aufgestellt:

NH1: Es gibt keinen Unterschied in der Integration der definierten didaktischen Erfolgsfaktoren zwischen den beiden Fallbeispielen A und B.

NH2: Es gibt keinen Unterschied in der Effizienz zwischen den beiden Fallbeispielen A und B durch die Anwendung der definierten didaktischen Erfolgsfaktoren.

NH3: Es gibt keinen Unterschied in der Effektivität zwischen den beiden Fallbeispielen A und B durch die Anwendung der definierten didaktischen Erfolgsfaktoren.

4.3. Fallbeispiele (Original und Adaptiert)

Das ursprüngliche SAP S/4 HANA CO-CCA Fallbeispiel (Bsp. A) wird auf Grundlage der didaktischen Erfolgsfaktoren analysiert. Aufgrund seines Umfangs wird das Fallbeispiel mit gezielter Auswahl auf fünf Aufgaben und vorgelagerter Übersicht begrenzt.

0. Übersicht über den Prozess
1. Kostenstellen anlegen
2. Planung der Leistungsausbringung
3. Planung von Primärkostenaufnahmen
4. Planung der innerbetrieblichen Leistungsaufnahmen
5. Überprüfung der Planung

Erfolgsfaktoren

Die Ergebnisse der Didaktik zeigen zwölf Elemente mit Relevanz für die Lehre. Für das aktuelle Fallbeispiel werden die Faktoren „Selbständiges Handeln“, "Spiel", "Inhalt im Kontext" und "didaktische Reduktion" nicht für die empirische Untersuchung herangezogen, sodass folgende notwendigen Erfolgsfaktoren identifiziert werden können: (1) Wiederholung, (2) Visualisierung, (3) Strukturierung, (4) Aufbau von Vorwissen, (5) Darstellung von Zusammenhängen, (6) Kommunikation des Ziels, (7) Leichter Stress durch Zeitvorgaben, (8) Mehrere Eingangskanäle

Fallbeispiel A (Original)

Im Anschluss wird die erste Aufgabe „Kostenstellen anlegen“, konzipiert im ursprünglichen Design des SAP-Fallbeispiels, genauer untersucht. Nachfolgend ein Auszug dieser ersten Aufgabe. Die genaue Analyse stellen die Autoren bei Anfrage zur Verfügung.

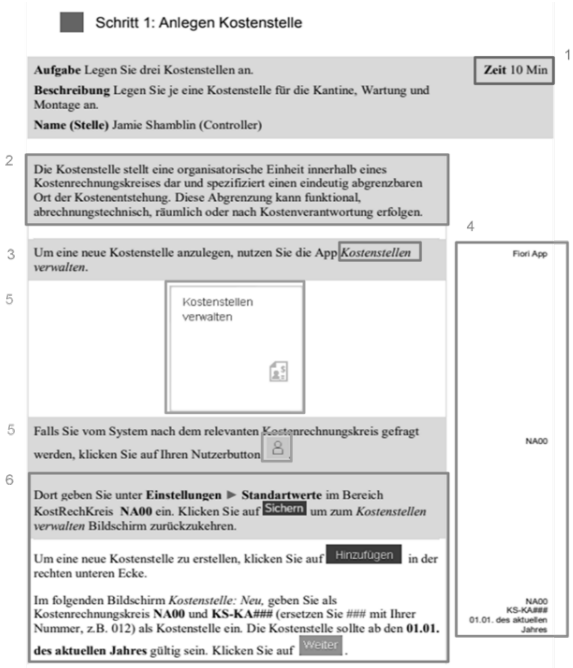


Abb. 1: Fallbeispiel SAP UA - Anlegen einer Kostenstelle (In Anlehnung an SAP University Alliances, 2019)

Das Fallbeispiel Kostenstellenrechnung (CO-CCA) (vgl. *Abb. 1*) zeigt, dass ein Großteil der abgeleiteten Erfolgsfaktoren bereits berücksichtigt wurde.

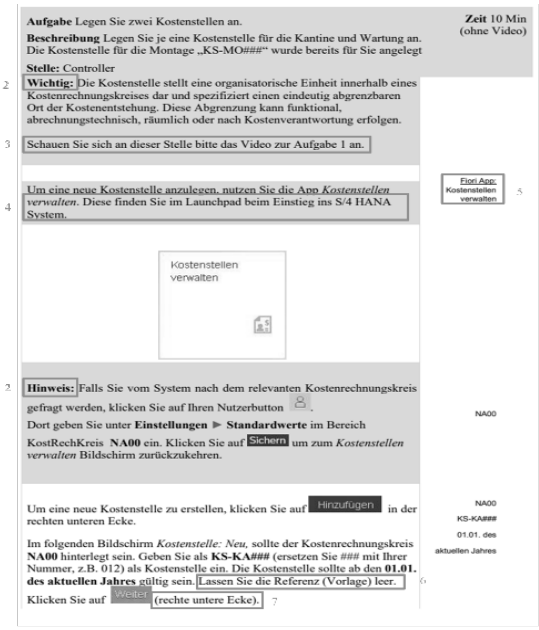
Potential für Verbesserung

1. Die Zeitangabe ist nicht präzise genug, um leichten Stress zu verursachen.
2. Damit die Lernenden auf Anhieb erkennen, dass es sich um Hintergrundinformationen handelt, ist eine Kennzeichnung als „Hinweis“ sinnvoll.
3. Die Leiste beschreibt nicht, um welche Informationen es sich handelt. Es steht z.B. nur "NA00" und nicht "Kostenrechnungskreis: NA00". Auch die Appbezeichnung ist nicht angegeben, hier steht nur "Fiori App", dies ist für SAP-Neulinge nicht ausreichend.
4. Es werden teilweise nur kleine Ausschnitte im Screenshot gezeigt, welche nicht erklären, wo das gesuchte System auf dem Bildschirm zu finden ist.

Durch das Anlegen verschiedener Kostenstellen ist der Faktor „Wiederholung“ insgesamt sehr präsent. Im Gegensatz dazu wurde der Faktor „mehrere Eingangskanäle“ nicht berücksichtigt, da weder Audio- noch Videokomponenten vorhanden sind.

Fallbeispiel B (Adaptiert)

Bei jeder Aufgabe des Fallbeispiels werden unterschiedliche didaktische Erfolgsfaktoren zur Verbesserung der Fallstudie angewendet. Aufgabe 1 *(Abb. 2)* nutzt die Erfolgsfaktoren Strukturierung, mehrere Eingangskanäle und Wiederholung. Andere Faktoren, wie z.B. die Zeitvorgabe, bleiben unverändert zur Originalversion.


Aufgabe Legen Sie zwei Kostenstellen an.

Zeit 10 Min (ohne Video)

Beschreibung Legen Sie je eine Kostenstelle für die Kantine und Wartung an. Die Kostenstelle für die Montage „KS-MO###" wurde bereits für Sie angelegt

Stelle: Controller

2 **Wichtig:** Die Kostenstelle stellt eine organisatorische Einheit innerhalb eines Kostenrechnungskreises dar und spezifiziert einen eindeutig abgrenzbaren Ort der Kostenentstehung. Diese Abgrenzung kann funktional, abrechnungstechnisch, räumlich oder nach Kostenverantwortung erfolgen.

3 Schauen Sie sich an dieser Stelle bitte das Video zur Aufgabe 1 an.

4 Um eine neue Kostenstelle anzulegen, nutzen Sie die App *Kostenstellen verwalten*. Diese finden Sie im Launchpad beim Einstieg ins S/4 HANA System.

Fiori App: Kostenstellen verwalten 5

Kostenstellen verwalten

2 **Hinweis:** Falls Sie vom System nach dem relevanten Kostenrechnungskreis gefragt werden, klicken Sie auf Ihren Nutzerbutton .

Dort geben Sie unter **Einstellungen** ► **Standardwerte** im Bereich KostRechKreis **NA00** ein. Klicken Sie auf Sichern um zum *Kostenstellen verwalten* Bildschirm zurückzukehren.

NA00

Um eine neue Kostenstelle zu erstellen, klicken Sie auf Hinzufügen in der rechten unteren Ecke.

Im folgenden Bildschirm *Kostenstelle: Neu,* sollte der Kostenrechnungskreis **NA00** hinterlegt sein. Geben Sie als **KS-KA###** (ersetzen Sie ### mit Ihrer Nummer, z.B. 012) als Kostenstelle ein. Die Kostenstelle sollte ab den **01.01. des aktuellen Jahres** gültig sein. Lassen Sie die Referenz (Vorlage) leer. 6

Klicken Sie auf Weiter (rechte untere Ecke). 7

NA00
KS-KA###
01.01. des aktuellen Jahres

Abb. 2: Aufgabe 1– verbessertes Fallbeispiel (In Anlehnung an SAP University Alliances, 2019)

1. Zur Strukturierung werden in einem ersten Schritt überflüssige Informationen entfernt.
2. Angaben wie "Wichtig" oder "Hinweis" werden zur Strukturverbesserung hinzugefügt.
3. Für eine effektivere Erklärung und Nutzung der verschiedenen Eingangskanäle wird ein Video integriert, das zeigt, wie eine Kostenstelle eingerichtet wird.
4. Wichtige Informationen werden zur besseren Strukturierung hinzugefügt.
5. Um die Wiederholung zu ermöglichen, wird ein wichtiger Hinweis (F4-Hilfe) hinzugefügt.
6. Die Screenshots werden aktualisiert, um die Struktur und Visualisierung zu optimieren.
    - Um sicherzustellen, dass die relevanten Informationen auf einer Seite sichtbar sind, werden neue Informationen zur Erhöhung der Struktur auf eine neue Seite verschoben.
7. Ein Screenshot wird zur Verbesserung der Visualisierung hinzugefügt.

4.4. Ergebnisse

Um signifikante Unterschiede in Effizienz und Effektivität zwischen Versuchs- und Kontrollgruppe festzustellen, wird der Wilcoxon-Mann-Whitney-Test (U-Test) durchgeführt (Döring und Bortz 2016, S. 705–707; Kosfeld et al. 2020, S. 318–320; Rasch et al. 2014, S. 33–35)

Auswertungen Effizienz

Tab. 1: Gesamtzeit (Eigene Darstellung)

(min)	μ	σ	U (Z=27)
A	34,00	15,09	
B	31,27	5,16	
Gesamt	32,57	10,85	n.s.

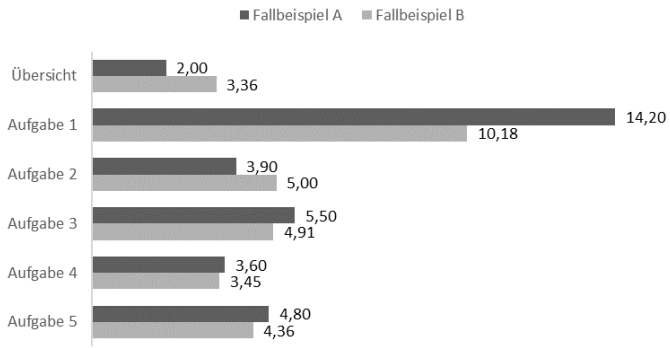


Abb. 3: Durchschnittliche Zeit pro Aufgabe (Eigene Darstellung)

Obwohl sich die erforderliche Gesamtzeit *(Tab. 1)* in Bezug auf den Mittelwert nicht signifikant verbessert hat, unterscheidet sich die maximal erforderliche Gesamtzeit deutlich. Der/die langsamste Studierende in Gruppe A benötigte 69 Minuten, in Gruppe B lediglich 40 Minuten. Weiters sind deutliche Zeitunterschiede pro Aufgabe (*Abb. 3*) zu erkennen.

Auswertungen Effektivität

Tab. 2: Fehlermeldungen (Eigene Darstellung)

	μ	**σ**	**U (Z=27)**
A	8,70	5,58	
B	3,55	2,34	
Gesamt	6,00	4,87	12

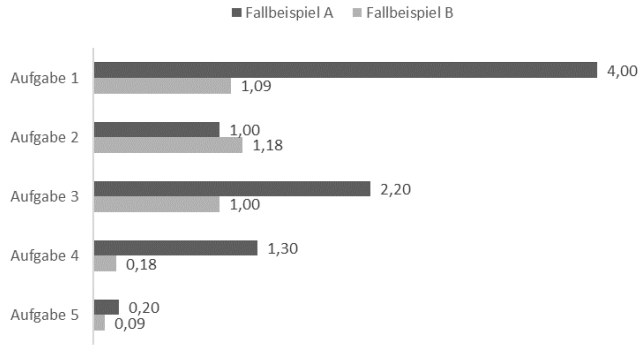


Abb. 4: Mittelwerte der Fehlermeldungen (Eigene Darstellung

In Gruppe B konnte in Hinblick auf die generierten Fehlermeldungen (*Tab. 2 und Abb. 4*) eine signifikante Verbesserung (U= 12; Z= 27) erzielt werden.

4.5. Ergebnisse für die einzelnen didaktischen Erfolgsfaktoren

Die *Integration* der acht didaktischen Erfolgsfaktoren bezieht sich auf die Stärke der Einbindung in die Aufgabenstellung des Fallbeispiels und wurde mittels Likert-Skala (1-6, 6 als beste Bewertung) durchgeführt. *Tab. 3* zeigt die unterschiedliche Integration je relevanten didaktischen Erfolgsfaktor. Die Integration von sechs der Erfolgsfaktoren zeigt hierbei eine signifikante Verbesserung mittels U-Test *(fett markiert)*, so dass die Nullhypothese verworfen werden muss.

Die Effizienz der einzelnen Erfolgsfaktoren adressiert die Wichtigkeit der Erfolgsfaktoren bei der schnellen Lösung der Aufgaben. *Tab. 3* zeigt, dass für sechs der Erfolgsfaktoren ein signifikanter Unterschied in der Effizienz festgestellt. In Gruppe B gab es eine Verbesserung in Bezug auf die Mittelwerte in den Bereichen „Visualisierung“, "Darstellung von Zusammenhängen", "Zeitvorgaben" und "mehrere Eingangskanäle“.

Für die Messung der Effektivität war die Wichtigkeit der Erfolgsfaktoren für die richtige Lösung der Aufgaben relevant. Fünf der Faktoren (*Tab.3*) weisen signifikante Unterschiede auf. Eine Verbesserung in der Gruppe B konnte dabei für die Faktoren "Wiederholung" „Visualisierung“ und "mehrere Eingangskanäle" erzielt werden.

Tab.: 3: Ergebnisse der Hypothesenüberprüfung (Eigene Darstellung)

EF[1]	**NH1: Integration**	**NH2: Effizienz**	**NH3: Effektivität**
Wiederholung	***μ= 5,00/5,18; U= -10****	n.s.	**μ= 4,60/ 5,09; U= 11**
Visualisierung	***μ= 4,80/5,82; U= -25***	**μ = 5,80/6,00; U= -7**	**μ = 5,60/5,91; U= 9**
Strukturierung	μ= 5,20/5,18; U= 19	μ= 5,50/5,45; U= 4	μ= 5,50/5,18; U= 4
Aufbau auf Vorwissen	**μ= 4,20/4,55; U= -20**	μ= 3,50/ 3,36; U= 25	μ= 3,40/ 3,36; U= 27
Darstellung von Zusammenhängen	**μ= 3,40/ 4,64; U= -2**	**μ= 3,20/3,73; U= 26**	n.s.
Kommunikation des Ziels	**μ= 4,90/ 4,91; U= -12**	n.s.	n.s.
Zeitvorgaben	n.s.	**μ= 3,30/4,45: U= 14**	n.s.
Mehrere Eingangskanäle	**μ = 4,20/5,45; U= -11**	**μ= 2,80/4,82; U= 0**	**μ = 3,50/ 4,82; U= 6**

* μ= A/B; kritischer Wert Z= 27

Im Rahmen der Überprüfung mittels qualitativer Inhaltsanalyse nach Mayring (1991) wurde, nach neuerlichem Aufgreifen der Kategorie „Vollständigkeit versus didaktische Reduktion“ aus der Literatur, folgende zusätzliche Erkenntnisse erzielt:

Beim Erfolgsfaktors *"Visualisierung"* (EF2) ist es wichtig zu beachten, dass die Screenshots konsistente Daten enthalten und keine unterschiedlichen Daten darstellen. Für die „*Strukturierung*“ (EF3) ist die unterschiedliche Hervorhebung der Schriftarten, einschließlich fettgedruckter Schrift relevant. Die Einfügung relevanter Informationen, wie Screenshots vor dem Text, erwies sich als die wichtigste Strukturkomponente. Die Videokomponenten im Fallbeispiel stellten sich für den Faktor „*Mehrere Eingangskanäle*“ (EF8) als wesentlich heraus. Das Fehlermeldungssystem des SAP-Systems wurde als vorteilhaft angesehen, da es besondere Kontrollmöglichkeiten bietet, die für SAP-Neulinge von Bedeutung sind. Es ist weiters von Bedeutung, dass Abkürzungen und Begriffe präzise definiert werden, um die Faktoren „*Inhalte im Kontext*“ und „*didaktische Reduktion*“ (EF9) ausreichend zu berücksichtigen.

5. Fazit und Ausblick

Die Lehre von SAP-Systemen profitiert vom Einsatz von Fallstudien, da somit erfolgreich spezifisches Software-Know-How vermittelt und langfristig hohe Praxisrelevanz kreiert werden kann. In diesem Beitrag wurde speziell die Wirkung von didaktischen Erfolgsfaktoren auf die Effizienz und Effektivität von bzw. deren Integration in einer Online-SAP-Fallstudie

analysiert. Es konnte hierbei gezeigt werden, wie essenziell spezifische didaktische Faktoren für den Einsatz in der Lehre sind. Nach Reduktion wurden folgende neun didaktische Erfolgsfaktoren für SAP-Online-Fallstudien berücksichtigt: (*1) Wiederholung, (2) Visualisierung, (3) Strukturierung, (4) Aufbau von Vorwissen, (5) Darstellung von Zusammenhängen, (6) Kommunikation des Ziels, (7) Leichter Stress durch Zeitvorgaben, (8) Mehrere Eingangskanäle, (9) Vollständigkeit vs. didaktische Reduktion (erst durch qualitative Inhaltsanalyse).*

Ein anhand dieser Erfolgsfaktoren optimiertes Fallbeispiel sollte von überflüssigen Informationen bereinigt bzw. durch relevantes Vorwissen ergänzt werden (*EF: (1), (4) und (5)*). Eine Überarbeitung der Grafiken und Screenshots ist im Hinblick auf benutzerfreundliche Informationsaufnahme, Konsistenz und Vollständigkeit relevant (*EF: (2) und (9)*). Im Hinblick auf optimale Strukturierung gilt es relevante Information hervorzuheben bzw. wichtige Infos vor dem Text zu platzieren (*EF3*). Zusätzlich wird eine Verbesserung der Zielsetzung und eine Präzisierung der notwendigen Aufgabendauer mittels Zeitangabe empfohlen (*EF: (6) und (7)*). Der für die Erhöhung der Benutzerfreundlichkeit relevanteste Erfolgsfaktor war die Anreicherung der Fallstudie um Videos (*EF8*). Dies zeigt, dass in der zukünftigen Online-Lehre im SAP-Unterricht mehrere Eingangskanäle (Einsatz von Videos) integriert werden soll, um die Usability der verwendeten Fallstudien signifikant zu erhöhen.

Limitationen im Hinblick auf Repräsentativität ergeben sich aufgrund der beschränkten Anzahl von Teilnehmern und der Auswahl der Teilnehmer aus einem Finanzstudiengang. Als Probanden wurden bewusst Studierende ohne SAP-Vorwissen selektiert, wodurch allerdings nur eine Teilmenge der Lernenden adressiert wurde. Auch eine subjektive Komponente durch das qualitative Forschungsdesign, insbesondere eine mögliche Beeinflussung durch die Studienleiterin, kann trotz aller Maßnahmen nicht komplett ausgeschlossen werden.

Weiterer Forschungsbedarf besteht in der Ergänzung der qualitativen um quantitative Untersuchungen und in der Erweiterung des Probandenspektrums auf Lernende mit SAP-Vorkenntnissen sowie auf Erweiterung des Lehrkonzeptes auf logistische Aspekte.

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Erwerb praktischer Fähigkeiten im wissenschaftlichen Studium der Wirtschaftsinformatik – ein Erfahrungsbericht

Barbara Rapp
Carl von Ossietzky Universität Oldenburg, Oldenburg, Deutschland

Abstract: Der Erfahrungsbericht gibt Einblicke in die konkrete Ausgestaltung der Lehrveranstaltung Praktikum Wirtschaftsinformatik an der Carl von Ossietzky Universität Oldenburg. Dargestellt wird wie verschiedene Methoden und Vorgehensweisen aus den Bereichen Design Thinking und Lean Startup ineinandergreifen können, um Studierende beim Aufbau verschiedener Kompetenzen zu unterstützen. Der Fokus liegt dabei auf dem Google Design Sprint, einem stark strukturierten Prozess, mit dessen Hilfe innerhalb einer Woche eine realweltliche Problemstellung untersucht und verstanden sowie eine dazu passende prototypische Lösung entwickelt werden kann. In der Lehrveranstaltung wird dies angereichert durch Liberating Structures, Storyteller Tactics, Workshop Tactics, verschiedene alternative Präsentationstechniken sowie einen Lego Serious Play Workshop und einen Sensorworkshop. Da das Konzept über die Jahre stetig überarbeitet und veränderten Bedingungen angepasst wurde, können an verschiedenen Stellen Empfehlungen und Hinweise ausgesprochen werden. Der Beitrag adressiert darüber hinaus kurz aktuelle Aufgaben, die jeweils durch einen Praxispartner beigesteuert wurden. Abgerundet wird der Erfahrungsbericht durch eine kritische Reflexion des Status quo.

Keywords: Google Design Sprint, Design Thinking, Lean Startup, Erfahrungsbericht, Methodenkoffer

1. Hintergrund

Der Bachelorstudiengang Wirtschaftsinformatik an der Carl von Ossietzky Universität Oldenburg erstreckt sich über eine Regelstudienzeit von sechs Semestern und umfasst 180 Kreditpunkte. Der Studiengang ist Bestandteil des Portfolios des Departments für Informatik.

Verschiedene grundlegende Informatikvorlesungen bilden das starke Fundament des Studiengangs – über ein Drittel der Kreditpunkte muss in diesem Bereich erfolgreich belegt werden. Die verbleibenden Kreditpunkte sind mit dem Kompetenzaufbau in den Bereichen der Wirtschaftsinformatik, der Wirtschafts- und Rechtswissenschaften, der Mathematik sowie dem Professionalisierungsbereich verbunden.

Die im Bachelor typische Lehrform ist die Vorlesung, häufig mit sehr vielen Teilnehmenden. Üblicherweise werden die zumeist theoretischen Vorlesungsinhalte durch fachpraktische Übungen ergänzt, die von den Studierenden häufig in Kleingruppen zu drei Personen asynchron bearbeitet werden. Gruppenprojekte, die für die meisten Studierenden später eine hohe berufliche Relevanz aufweisen, sind aufgrund des hohen Betreuungsaufwands eher selten.

Die in diesem Paper vorgestellte Lehrveranstaltung Praktikum Wirtschaftsinformatik bietet den Teilnehmenden die Möglichkeit, ihre Soft Skills- sowie Softwaredesign- und Programmierkenntnisse umfangreich im Rahmen eines Projektes mit starkem Praxisbezug zu erweitern. Im nachfolgenden Kapitel werden das inhaltliche und didaktische Konzept des

Moduls sowie verschiedene Aufgabenstellungen der letzten Jahre vorgestellt. Das Paper schließt mit einer kritischen Reflexion des bisher erreichten und zeigt Limitationen auf.

2. Konzept der Lehrveranstaltung

Bei den ersten Überlegungen zur Veranstaltung war angedacht, sie als fakultatives Angebot im Masterstudiengang Wirtschaftsinformatik anzubieten. Dies hätte als Warm-up für das Master-Kernmodul Projektgruppe genutzt werden können. Allerdings ist der viersemestrige Master recht eng getaktet, insbesondere wenn die Möglichkeit eines Auslandssemesters gewahrt bleiben soll.

Daraufhin wurde beschlossen, das Modul als Vorbereitung auf die Durchführung der Bachelorarbeit zu konzipieren und (insbesondere) für Studierende ab dem vierten Semester anzubieten. Diese Studierenden bringen neben theoretischen Kenntnissen auch praktische Erfahrungen im Softwaredesign und der Programmierung mit. Darüber hinaus verfügen diese Studierenden auch über erste Erfahrungen im agilen Projekt- sowie Konfliktmanagement. Ebenfalls sind sie im wissenschaftlichen Arbeiten geübt. Wo sie zumeist schwach aufgestellt sind, sind Kreativitätstechniken und insbesondere Aspekte des Design Thinkings und Lean Startups. Eine der größten Herausforderungen bei der selbstorganisierten Anfertigung der Bachelorarbeit ist, dass ihr bisheriger Methodenkoffer (erworbenes Wissen, Verfahren und Vorgehensweisen aus obigen Themenkomplexen) kaum geeignet ist, ein Projekt allein zu bearbeiten, da ihre bisherigen Projekterfahrungen i.d.R. aus Gruppen mit acht oder mehr Personen stammen.

Beim Praktikum Wirtschaftsinformatik handelt es sich um einen zweiwöchigen Blockkurs, der jeweils in der vorlesungsfreien Zeit im Wintersemester (üblicherweise in Präsenz) angeboten wird. Die Veranstaltung folgt zeitlich auf die Klausurenphase und wird möglichst überschneidungsfrei geplant. Die erste Woche (auch Inputwoche genannt) startet am Montagmorgen mit verschiedenen Teambuildings. Da die Studierenden i.d.R. nicht aus einer Kohorte stammen, kennen sie sich nicht zwangsläufig – dies ist aber unabdingbar für das Format des Kurses. Begonnen wird mit Story Cubes. Hierbei handelt es sich um neun Würfel, wobei jede Seite mit einem anderen Symbol bedruckt ist. Nach dem Wurf muss nun jeder Teilnehmende basierend auf den oben liegenden Symbolen etwas über sich erzählen, z.B. Persönlichkeit, Vorerfahrungen, besondere Fähigkeiten, etc.; die Dozierenden beginnen. Diese Form der Vorstellung sorgt dafür, dass die Studierenden mehr als ihren Namen und ihr Hochschulsemester angeben; die Erfahrung zeigt, dass alle im Anschluss sehr gut miteinander ins Gespräch kommen und sich die (im späteren Verlauf wichtigen) Kleingruppen leichter zusammenfinden. Im Anschluss spielen die Studierenden 5-Minute-Dungeon; ein chaotisches, kooperatives, Echtzeit-Kartenspiel in dem Kommunikation und Zusammenarbeit entscheidend sind um die vorgegebenen Ziele zu erreichen. Dieses Spiel wurde nicht nur wegen des sehr zugänglichen Regelwerks und des sehr kommunikativen Ansatzes ausgewählt, sondern insbesondere auch, da jede Runde exakt fünf Minuten dauert und sich somit die Gesamtdauer gut bestimmen lässt. Nach diesem, für eine Lehrveranstaltung, eher untypischen Start steht das Thema Google Design Sprint im Fokus.

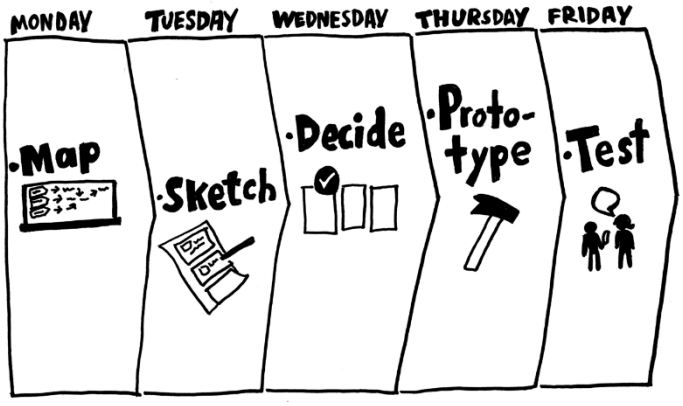

Abb. 1: Google Design Sprint nach Knapp et al. 2016

Der Google Design Sprint (GDS) wurde ab 2012 bei Google Ventures entwickelt (Knapp et al. 2016). Es handelt sich dabei um einen stark strukturieren fünftägigen Prozess (siehe Abb. 1), mit dessen Hilfe ein gegebenes Problem innerhalb kürzester Zeit prototypisch umgesetzt wird. Der GDS besteht dabei aus den Phasen map, sketch, decide, prototype und validate. In der ersten Phase (Montag) widmet man sich dem Problemverständnis und der exakten Formulierung des Ziels. Hierfür bietet sich der Einsatz der Methoden How Might We, Mad Tea Party oder 1-2-4-all an. Diesen Methoden ist gemein, dass sie einen Perspektivwechsel herbeiführen, verschiedene Sichten auf die einzelnen Aspekte der Problemstellung sammeln und auch zurückhaltende Teilnehmende aktivieren. Mittels How Might We werden Probleme (Beispiel: Kunde sagt, bei technischen Problemen dauert es immer ewig bis mir geholfen wird.) in Möglichkeiten (Wie können wir unseren Kunden schneller bei technischen Problemen helfen?) überführt. Mit Hilfe der Methoden 1-2-4-all kann es innerhalb von 12 Minuten gelingen, verschiedenste Ideen urteils- und wiederholungsfrei zu einer konkreten Fragestellung zu generieren, indem die Ideengenerierung und die Gruppendiskussion getrennt werden. Dafür macht sich jede Person zunächst allein Gedanken zur entsprechenden Fragestellung, im Anschluss werden die jeweils eigenen Ideen einer zweiten Person vorgestellt und mit dieser weiterentwickelt. In einem nächsten Schritt werden die bereits gefundenen Ideen zu viert verfeinert, wobei insbesondere auf Gemeinsamkeiten und Unterschiede zu achten ist. Abschließend werden die (besonders bemerkenswerten) Ideen im Plenum vorgestellt.

Diese Vorarbeiten bilden die Grundlage für die zweite Phase (Dienstag), das Sketching. Hier werden, typischerweise mittels der Methode Crazy 8's, bereits (am Markt) bestehende Lösungen kritisch betrachtet (remix and improve) und aus den abstrakten Ideen der Mapping-Phase Lösungen generiert; i.d.R. acht Varianten derselben Idee. Nach einer kurzen Präsentation der einzelnen Ideen werden die jeweils besten Aspekte in einem Solution Sketch konsolidiert. Um nun aus der Menge an Ideen und Lösungen die besten und/oder angemessensten identifizieren zu können, wird in die Phase Decide (Mittwoch) gewechselt. Hier haben sich in unserer Praxis die Methoden Art Museum, Heat Map, Speed Critique und Straw Poll als besonders zielführend hervorgetan. Hierbei handelt es sich um verschiedene Möglichkeiten der Abstimmung. Sie reichen von einfachen Dot Vote-basierten Heat Maps (ein Abstimmungsergebnis je Lösungskandidat) bis hin zum Art Museum (ein Abstimmungsergebnis über alle Lösungskandidaten). Hierbei werden alle Lösungsoptionen nebeneinander präsentiert und die Teilnehmenden können die in ihren Augen beste Idee sowie das beste Feature markieren und ggf. auch jeweils Notizen hinterlassen. Der wichtigste Output

der dritten Phase ist jedoch das Storyboard. Dieses enthält alle relevanten Elemente (in Form von Szenen), die für den Prototypen umgesetzt werden sollen.

Genaugenommen ist das Storyboard das zentrale Element des gesamten Sprints, es konsolidiert alle wichtigen Ideen und Lösungsansätze (Ergebnisse der Vorphasen), strukturiert diese entlang einer Storyline und bildet die Grundlage für die nachfolgende Umsetzung des Prototyps. Ein Storyboard ist eine Abfolge von Zeichnungen, wobei mit der Eröffnungsszene begonnen wird und über (i.d.R.) 10-15 Frames das Vorgehen zur Lösung des gegebenen Problems schrittweise nachvollzogen werden kann. Eine große Herausforderung stellt das Anfertigen dieser Zeichnungen dar, insbesondere, da auf kleinstem Raum alle wesentlichen Elemente enthalten und vor allem eindeutig erkennbar sein müssen. Da nicht Jeder im Zeichnen geübt ist, bietet sich hier der Einsatz spezifischer Software an. Im Rahmen der Lehrveranstaltung nutzen wir bereits seit mehreren Jahren sehr erfolgreich SAP Scenes. Hierbei handelt es sich um eine SAP AppHaus- Entwicklung, die unter Creative Commons (CC BY-NC-SA 4.0) lizensiert ist. Scenes stellt verschiedenste graphische Elemente (siehe Abb. 2) zur Verfügung, die beliebig miteinander kombiniert werden können, um so unterschiedliche Anwendungsfälle realisieren zu können. In der Basisvariante sind dies neben Personen, Gebäuden, Einrichtungsgegenständen und Hintergründen auch elementare Dinge wie beispielsweise Sprechblasen und Pfeile. Darüber hinaus gibt es aktuell Add-ons zu den Themen Gesundheitswesen, Einzelhandel und Logistik sowie zusätzliche Charaktere und Hintergründe. Scenes kann sowohl digital als auch in der Form von physischen Aufstellern genutzt werden. Im Rahmen der Lehrveranstaltung nutzen wir stets die digitale Variante; nicht nur unter dem Aspekt der Ressourcenschonung, sondern auch, um die Kollaboration zwischen den Studierenden insbesondere in Online-Settings zu erleichtern.

Abb. 2: Wesentliche Scenes-Elemente

Am darauffolgenden Tag (Donnerstag) wird der Prototyp fertiggestellt. Dieser Idee stehen die Studierenden typischerweise sehr skeptisch gegenüber, ihrer Meinung nach ist dies an einem Tag nicht möglich. Tatsächlich ist die Erstellung des Prototyps innerhalb eines Tages realistisch, da alle notwendigen Entscheidungen bereits begründet getroffen und auch im Storyboard berücksichtigt wurden. Für die Realisierung selbst bietet sich die Strategie divide and conquer an. Dafür wird das Storyboard in kleinere Szenen aufgeteilt und den entsprechenden Mitgliedern der Gruppe zugeteilt. Der Google Design Sprint endet mit der Evaluation des Prototyps am Freitag, i.d.R. wird der Prototyp dafür Personen aus der Zielgruppe präsentiert. Je nach Aufgabenstellung bietet sich hierfür die Übernahme von bekannten Settings aus dem Usability-Testing an. Neben dem Design Sprint werden auch Liberating Structures (Lipmanowicz & McCandless 2014), Storyteller Tactics und Workshop Tactics (https://pipdecks.com) adressiert. Hieraus werden ausgewählte Methoden und Techniken

beispielsweise zur Generierung von Ideen oder Präsentation dieser besprochen, die den Methodenkoffer der Studierenden bereichern sollen.

Die einzelnen Phasen des Google Design Sprints sowie die Möglichkeiten von Liberating Structures, Storyteller Tactics und Workshop Tactics werden von den teilnehmenden Studierenden im Vorfeld zum Kurs aufbereitet, wobei die Zuordnung der einzelnen Themen auf einzelne Personen bei den Studierenden liegt. Jedes Thema wird in einer 45-minütigen Lehreinheit präsentiert, wobei zunächst ein wissenschaftliches Poster auf die theoretischen Grundlagen eingeht. Ebenfalls müssen die Studierenden eine Übungseinheit – maßgeschneidert auf ihr jeweiliges Thema – durchführen und ihren Kommilitonen Feedback zu deren Lösungsvorschlägen geben. Im Anschluss daran erhalten alle Studierende eine vertiefende Aufgabe von der Dozentin. In Summe ergeben sich 90 Minuten pro Einzelthema als Plangröße. Neben den bereits genannten Themen werden auch weitere Möglichkeiten der Präsentation, wie Pecha Kucha oder Pitches besprochen und geübt. Ebenso werden die Möglichkeiten der KI-unterstützten Videoerstellung besprochen.

Die erste Kurswoche ist mit den Themen Team Building, Google Design Sprint, Liberating Structures, Storyteller und Workshop Tactics, Präsentationstechniken und Videoerstellung von Montagmorgen bis Mittwochnachmittag gut bestückt und wird größtenteils durch die – von den Studierenden ausgestalteten – Lehreinheiten bestimmt. Donnerstag und Freitagvormittag der ersten Kurswoche sind reserviert für zwei Workshops, den Lego Serious Play Workshop und den Sensorworkshop. Bei Lego Serious Play (https://www.lego.com/de-de/themes/serious-play) handelt es sich um ein moderiertes Format, in dem Problemlösungskompetenzen, Reflexion und Dialog mittels Modellierung mit Legosteinen gestärkt werden sollen. Für den Einstieg werden zunächst Objekte nach Anleitung gebaut. In einer weiteren Iteration werden individuelle Modifikationen vorgenommen und im Nachgang erläutert. Im Fokus des Workshops steht allerding das freie Bauen, also das Umsetzen eigener Ideen ohne Bauanleitung (Abb. 3 zeigt ein Beispiel). Eine Herausforderung hierbei ist, dass nicht alles unmittelbar über Legosteine abgebildet werden kann, es bedarf zumeist Metaphern – ein konkreter Baustein erhält eine übertragene Bedeutung und kann so einem abstrakten Konzept Gestalt geben. Auch diese Methode soll die Studierenden befähigen, eine Problemstellung von einer globalen Perspektive aus zu betrachten und dabei die relevanten Aspekte zu identifizieren und sich nicht in Details zu verlieren. Nachdem jedes (individuelle) Modell nach jeder Runde erläutert wird, soll im Rahmen der letzten Aufgabe eine gemeinsame Antwort auf eine im Vorfeld festgelegte Fragestellung gefunden werden. Hierbei steht neben dem Finden geeigneter Metaphern die Kommunikation im Vordergrund.

Abb. 3: Individuelle Interpretation des perfekten Arbeitsplatzes durch eine Studierende.

Da die Studierenden in den letzten Veranstaltungsdurchläufen zumeist Hardware-/Software-Prototypen entwickeln sollten, findet am Freitagvormittag der Sensorworkshop statt. Hier bearbeiten die Studierenden in Zweiergruppen kleine Projekte und realisieren in der Einsteigervariante z.B. den rotierenden Farbwechsel einer RGB-LED oder ein Thermometer mittels Thermistor. Da der Wissensstand im Vorfeld in Erfahrung gebracht wird, kann der Schwierigkeitsgrad der Aufgaben entsprechend justiert werden. Für den Fall das kein Bedarf am Sensorworkshop besteht, könnte z.B. die KI-unterstützte Videoerstellung und hier insbesondere die Nutzung von Avataren im Detail beleuchtet werden.

Nachdem nun der Methodenkoffer der Studierenden gut gefüllt ist, findet am Freitagnachmittag die Präsentation der Aufgabenstellung durch den Praxispartner statt. Dieser motiviert das Thema, umreißt die Problemstellung und stellt seine Erwartungen an den zu entwickelnden Prototypen vor. Die im ersten Anlauf präsentierte Aufgabenstellung ist absichtlich zu groß. Es ist nun die Aufgabe der Studierenden auch mithilfe ihres neu erworbenen Wissens den eigentlichen Kern der Aufgabenstellung zu ermitteln und einen passgenauen Prototypen zu entwickeln. Hierfür gibt es verschiedene Möglichkeiten dem Praxispartner Fragen zu stellen, um sich rückzuversichern.

Den Abschluss der ersten Woche bildet eine weitere Team Building-Maßnahme; gern adaptieren wir die Marshmallow oder die Straw Bridge Challenge. Hier gewinnt jeweils das Team, welches aus einer beschränkten Menge an Ressourcen den höchsten Turm bzw. die stabilste Brücke baut.

Allen Tagen in der ersten Woche ist gemein, dass sie stark durchgetaktet sind. Dies ist zum einen in der Themenvielfalt begründet, zum anderen sind die Studierenden so angehalten sich auf die wesentlichen Aspekte der Aufgabenstellung zu fokussieren sowie zügig und strukturiert zu einem Ergebnis zu gelangen; insbesondere gilt es bike shedding zu vermeiden.

Die zweite Kurswoche (Outputwoche) verfügt über kein festes Programm, lediglich ein kurzes tägliches Stand-up ist für alle Gruppen verpflichtend. Hierbei können Herausforderungen und Hindernisse besprochen und (hoffentlich) gelöst werden, selbstverständlich kann auch über Fortschritte berichtet werden. Die Bearbeitung der Praxisaufgabe erfolgt selbstorganisiert durch die Studierenden, wobei Räumlichkeiten und die (vermutlich) benötigte Hardware gestellt wird. Deadline für die Gruppenarbeit sind die Pitches der einzelnen Arbeiten am Freitagnachmittag der zweiten Woche. Typischerweise wird der Google Design Sprint von den Studierenden nicht in Reinform realisiert, sondern an ihre Bedürfnisse angepasst. Hierfür werden zumeist die Phasen map, sketch und decide an zwei Tagen abgearbeitet. Für die Phasen prototype und test werden üblicherweise anderthalb Tage geplant, sodass am Donnerstagnachmittag der Pitch vorbreitet werden kann; Freitagvormittag dient als Puffer. Während der gesamten Zeit steht die Dozentin für Rückfragen und Feedback zur Verfügung.

Unsere Erfahrung über die Jahre zeigt, dass eine Bearbeitung der Praxisaufgabe in Gruppen mit drei bis vier Personen die besten Ergebnisse liefert. Größere Gruppen gehen häufig mit einem höheren Koordinationsaufwand einher, zurückhaltende Charaktere können schlechter aktiviert werden und dominante Charaktere erhalten zu viel Raum. Die Gruppenfindung sollte durch die Studierenden erfolgen und spätestens vor der Präsentation der Praxisaufgabe abgeschlossen sein.

In der Vergangenheit sollten die Studierenden sowohl Strategien und Konzepte, als auch reine Software oder kombinierte Hard- und Software prototypisch entwickeln. An dieser Stelle sollen zwei Praxisaufgaben kurz vorgestellt werden; zunächst die Low-Cost-Klimastationen, danach

das AR-unterstützte Repair Cafe. Auf Initiative des regionalen Wasserverbandes sollte eine möglichst kostengünstige Klimastation entworfen werden, mit deren Hilfe eine kleinräumige Starkregengefahr (Stadtteile, idealerweise Straßenzüge) vorhergesagt werden kann. Dabei sollten zusätzlich Aspekte wie Flottenmanagement, automatisierte Datenauswertungen, Vorkehrungen gegen Vandalismus und Diebstahl sowie Partizipation der Bürger:innen und der Datenschutz berücksichtigt werden. Erwartet wurde eine Kombination aus Hard- und Softwareprototyp. Für die Studierenden standen SenseBoxen sowie UNO R3-Bausätze mit jeweils entsprechenden Aktuatoren und Sensoren sowie verschiedene 3D-Drucker zur Verfügung.

Für das AR-unterstützte Repair Cafe bestand die Aufgabe darin, Reparateure mittels Augmented Reality in ihren Tätigkeiten zu unterstützen. Dafür haben die Studierenden ein ganzheitliches Konzept in Form einer App entwickelt, welche beispielsweise Schritt-für-Schritt-Anleitungen für bestimmte Reparaturen liefert oder auch die Anzahl der Fokuswechsel minimiert sowie die Dokumentation der durchgeführten Reparaturen inhaltlich unterstützt. Den Studierenden stand eine Hololense zur freien Verfügung. Für die Realisierung von App-Prototypen kommt mittlerweile häufig Figma zum Einsatz. Früher wurde oft auch SAP Build bzw. Adobe XD eingesetzt.

Die Prüfungsleistung für den Blockkurs setzt sich aus einem Individual- und einem Gruppenanteil zusammen. Jede Person muss ein wissenschaftliches Poster erstellen und präsentieren, wobei verschiedene Themen (Inhalte der ersten Kurswoche) zur Wahl stehen. Zusätzlich muss eine thematisch dazu passende Übungseinheit durchgeführt werden. Darüber hinaus muss jede Gruppe ihren Prototypen sowie die Vorgehensweise bei der Realisierung pitchen, zusätzlich ist ein Produktvideo zu erstellen.

3. Reflexion

Das Praktikum Wirtschaftsinformatik wird seit dem Wintersemester 2017/2018 jährlich angeboten und wurde schrittweise – auch basierend auf dem Feedback der Studierenden – konzeptionell modifiziert. In den Jahren vor Corona haben ca. 15-20 Studierende die Prüfungsleistungen abgelegt. Während der Lockdowns waren es nur sechs Teilnehmende und in der Nach-Corona-Zeit hat sich die Teilnehmendenzahl auf 10-12 Studierende eingependelt. Die geringere Nachfrage spiegelt die Entwicklungen der Studienanfängerzahlen (nach Corona) sehr gut wieder. Aus Sicht der Dozierenden ist diese Entwicklung nicht zwangsläufig nachteilig, da das aktuelle Setting sehr betreuungsintensiv ist; jede Lösung ist einzigartig und muss daher individuell bewertet werden – eine Generalisierung insbesondere bei der Notenfindung ist nicht möglich. Sehr gute Erfahrungen wurden mit dem hier vorgestellten Konzept bei der Umsetzung von reinen Software- oder kombinierten Hardware-/Software-Prototypen gemacht. Weniger geeignet scheint das Konzept bei der reinen Strategie- und Konzeptentwicklung zu sein. Hier sind weitere Versuche beabsichtigt.

Der Mehrwert für die Teilnehmenden besteht insbesondere darin, eine abstrakte realweltliche Problemstellung – d.h. keine Fallstudie oder sonstige artifizielle Daten – soweit zu durchdringen, um eine passende Forschungsfrage formulieren zu können. Die Praxisaufgabe ist bewusst zu groß für die zur Verfügung stehenden Ressourcen (Zeit und Arbeitskraft) gewählt. Die Studierenden müssen also die relevanten Inhalte identifizieren und ein entsprechendes Zeit- und Aufgabenmanagement in ihren Kleingruppen organisieren. Die erworbenen Kompetenzen (z.B. der Methodenkoffer) lassen sich direkt auf andere größere oder auch kleinere Projekte

inner- und außerhalb des Studiums und vor allem auf die Bachelorarbeit übertragen. Der herrschende Zeitdruck wird von den Studierenden zunächst als anstrengend empfunden. Dies ändert sich im Verlauf, da es ihnen stets leichter fällt die verschiedenen Aufgabenstellungen zu verstehen, auf das Wesentliche zu reduzieren und ihre Antworten zielgruppengerecht aufzubereiten. Ebenfalls sind sie es nicht gewohnt bereits unvollständige Lösungen bzw. Teilergebnisse einem Publikum zu präsentieren. Durch den stetigen Kompetenzausbau nimmt ihre Souveränität im Umgang damit zu. Die Festlegung auf eine Gruppengröße von drei bis vier Personen verteilt viel Verantwortung und Zuständigkeiten auf jede einzelne Person. Die Erfahrung zeigt jedoch, dass die Studierenden dem gewachsen sind und reduzierte Koordinationsaufwände nutzenstiftend sind.

Jedes Semester wählt die Fakultät Veranstaltungen, insbesondere Vorlesungen und große Seminare zur Evaluation aus, das Praktikum fällt leider nicht darunter. Dennoch wird das Feedback der Studierenden (siehe oben) erfasst und berücksichtigt. Beobachtungen und Rückmeldungen der Kolleg:innen zeigen, dass Praktikumsteilnehmer:innen ihre Bachelorarbeit im Anschluss sehr strukturiert und ingenieursmäßig bearbeiten. In der Vergangenheit haben sich ca. 56% der Absolvent:innen des Fachbachelors in den Master Wirtschaftsinformatik eingeschrieben, auch hier sind die Praktikumsteilnehmer:innen aufgrund ihrer Expertise positiv in den Projektgruppen sowie anderen Modulen mit Projektcharakter aufgefallen.

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Duale Hochschulen als Treiber von Innovationen durch den Einsatz von SAP in der Lehre

Christof Ipsen
NORDAKADEMIE Hochschule der Wirtschaft, Elmshorn, Deutschland

Abstract: In einer globalisierten und digitalisierten Welt ist Innovation der Schlüssel zum Erfolg. Unternehmen müssen ständig neue Wege finden, um wettbewerbsfähig zu bleiben und ihren Kunden die besten Lösungen anzubieten. Ein Unternehmensbereich, der besonders stark von Innovationen geprägt ist, ist die Informationstechnologie (IT). Innerhalb dieses Bereichs spielen ERP-Systeme – insbesondere SAP – eine zentrale Rolle. Durch den aktiven Einsatz von SAP in Vorlesungen und Seminaren können duale Hochschulen zu Treibern von Innovationen in deren Kooperationsunternehmen und für SAP werden.

1. Duale Hochschulen als Innovationsmotor

Duale Hochschulen kombinieren akademische Ausbildung mit praktischer Berufserfahrung. Studierende verbringen ihre Zeit sowohl in Vorlesungen als auch in Unternehmen, in welchen das Gelernte direkt anwenden können. Diese Form der Ausbildung hat zahlreiche Vorteile:

Praxisnahe Ausbildung: Studierende erwerben nicht nur theoretisches Wissen, sondern auch praktische Fähigkeiten, die in der Arbeitswelt gefragt sind und eine nahtlose Integration in den Arbeitsmarkt ermöglichen.

Direkter Wissenstransfer: Durch den ständigen Wechsel zwischen Hochschule und Unternehmen findet ein kontinuierlicher Wissenstransfer statt. Neue Ideen und Innovationen können sofort im Unternehmenskontext getestet und weiterentwickelt werden.

Enger Kontakt zur Wirtschaft: Duale Hochschulen arbeiten eng mit (Kooperations-) Unternehmen zusammen. Dies ermöglicht einen ständigen Austausch über aktuelle Herausforderungen und Trends in der Wirtschaft, was sich wiederum positiv auf die (deren) Innovationsfähigkeit auswirkt.

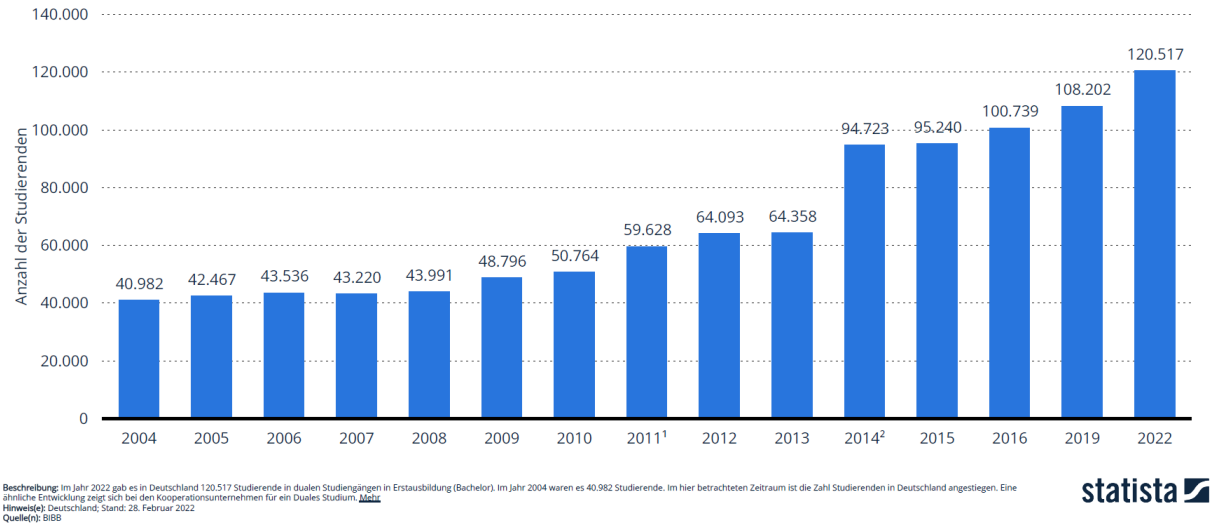

Abbildung 1: Dual Studierende (Bachelor) in Deutschland (Statista, 2022)

2. SAP in der Lehre an dualen Hochschulen

Die Integration von SAP in Vorlesungen an dualen Hochschulen wie der NORDAKADEMIE bietet zahlreiche Vorteile für Studierende, Unternehmen und die Hochschulen selbst.

2.1. Vorteile für Studierende

Erwerb von Schlüsselkompetenzen: Der Umgang mit SAP-Software erfordert ein tiefes Verständnis für betriebswirtschaftliche Prozesse und IT-Kenntnisse. Studierende erwerben somit wertvolle Fähigkeiten, die in vielen Unternehmen gefragt sind.

Erhöhte Beschäftigungsfähigkeit: Da SAP in vielen Unternehmen weltweit eingesetzt wird, sind Kenntnisse in der Anwendung dieser Software ein großer Vorteil auf dem Arbeitsmarkt. Absolventen dualer Hochschulen mit SAP-Kenntnissen sind daher besonders gefragt.

Praxisnahe Ausbildung: Die Anwendung von SAP in realen Projekten und Fallstudien ermöglicht es den Studierenden, das Gelernte direkt anzuwenden und zu vertiefen. Dies fördert ein besseres Verständnis und bereitet sie besser auf ihre zukünftige berufliche Laufbahn vor.

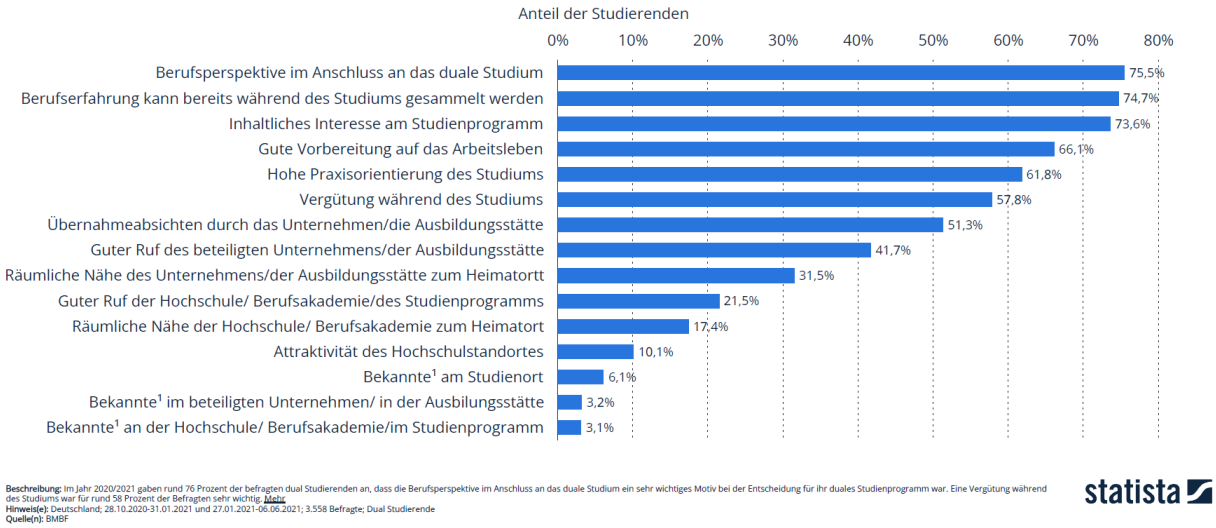

Abbildung 2: Vorteile eines dualen Studiums aus Sicht der Studierenden (Statista, 2021)

2.2. Vorteile für (Kooperations-) Unternehmen

Frühzeitige Talententwicklung: Unternehmen, die mit dualen Hochschulen zusammenarbeiten, können frühzeitig Talente identifizieren und fördern. Dies ermöglicht eine gezielte Ausbildung und Integration der Studierenden in das Unternehmen.

Innovationspotenzial: Durch die enge Zusammenarbeit mit Hochschulen erhalten Unternehmen Zugang zu neuen Ideen und Forschungsergebnissen. Dies kann zur Entwicklung innovativer Produkte und Lösungen beitragen.

Kosteneffizienz: Die Ausbildung von Studierenden an dualen Hochschulen ist oft kosteneffizienter als die Rekrutierung und Einarbeitung von Absolventen ohne praktische Erfahrung. Zudem können Unternehmen von den frischen Ideen und dem aktuellen Wissen der Studierenden profitieren.

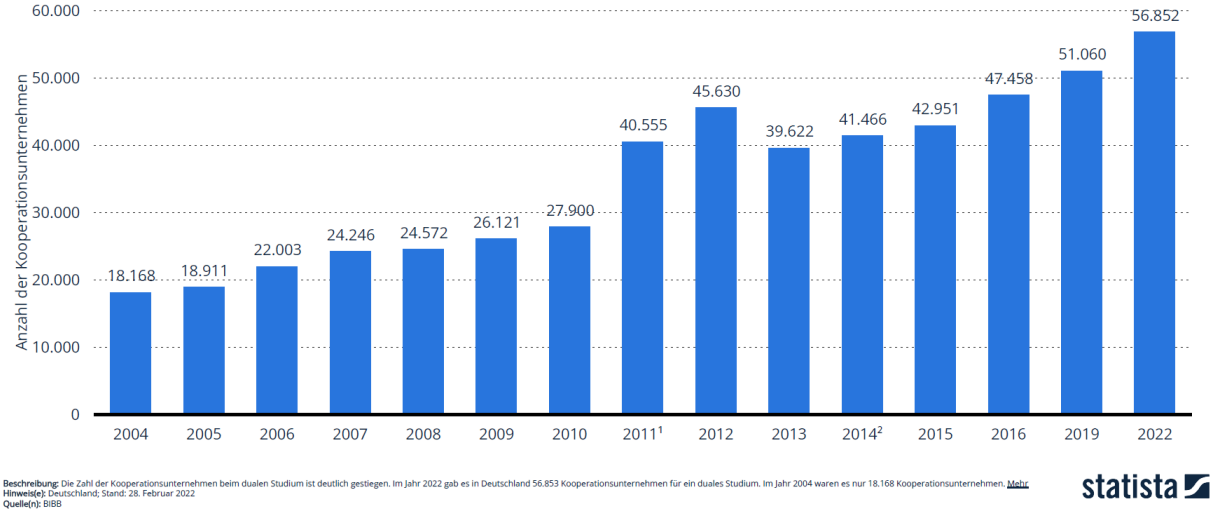

Abbildung 2: Vorteile eines dualen Studiums aus Sicht der Studierenden (Statista, 2022)

2.3. Vorteile für die Hochschulen

Attraktive Studienangebote: Die Integration von SAP in die Lehre macht die Studienangebote dualer Hochschulen attraktiver. Dies kann dazu beitragen, mehr Studierende anzuziehen und die Reputation der Hochschule zu stärken.

Förderung der Forschung: Die Zusammenarbeit mit Unternehmen bietet Hochschulen die Möglichkeit, praxisrelevante Forschung zu betreiben. Dies kann zur Entwicklung neuer Lehrmethoden und -inhalte beitragen.

Netzwerkbildung: Durch die Kooperation mit Unternehmen können Hochschulen ihr Netzwerk erweitern und neue Partnerschaften eingehen. Dies kann zu weiteren Forschungsprojekten und Fördermöglichkeiten führen.

3. NORDAKADEMIE und SAP

Die NORDAKADEMIE gAG ist seit 1992 die private, staatlich anerkannte Hochschule der Wirtschaft in Elmshorn (duale Bachelorstudiengänge) und später auch in Hamburg (berufsbegleitende Masterstudiengänge). Sie wird als gemeinnützige Einrichtung unmittelbar von Unternehmen getragen.

Die NORDAKADEMIE bildet in enger Zusammenarbeit mit ihren Kooperationsbetrieben praxisgerecht qualifizierte Nachwuchskräfte aus und befähigt diese, sich kommunikativ, engagiert, verantwortungsbewusst und kompetent den ihnen übertragenen Fach- und Führungsaufgaben in der Wirtschaft zu stellen.

3.1. Integration von SAP in die Lehre

An der NORDAKADEMIE wird SAP in verschiedenen Vorlesungen und Projekten eingesetzt. Dies umfasst sowohl theoretische als auch praktische Aspekte:

Theoretische Grundlagen: In Vorlesungen lernen die Studierenden die theoretischen Grundlagen von SAP und Unternehmenssoftware kennen. Dies umfasst Themen wie ERP-Systeme, Geschäftsprozessmanagement und Datenintegration oder auch Process Mining.

Praktische Anwendung: In praktischen Übungen und Projekten wenden die Studierenden das Gelernte an. Dies umfasst die Konfiguration und Anpassung von SAP-Modulen, die Durchführung von Geschäftsprozessen und die Analyse von Daten.

SAP-Zertifizierungen: Veranstaltungen der NORDAKADEMIE bereiten mittelbar auf Zertifizierungskurse vor. Diese Zertifizierungen sind weltweit anerkannt und erhöhen die Beschäftigungsfähigkeit der Absolventen.

3.2. Kooperation mit Unternehmen

Die NORDAKADEMIE arbeitet eng mit verschiedenen Unternehmen zusammen, die SAP einsetzen. Dies umfasst sowohl große multinationale Konzerne als auch mittelständische Unternehmen. Die Zusammenarbeit erfolgt auf verschiedenen Ebenen:

Praktika und Praxisphasen: Studierende absolvieren regelmäßig Praktika und Praxisphasen in Unternehmen. Dabei haben sie die Möglichkeit, ihre SAP-Kenntnisse in realen Projekten anzuwenden und zu vertiefen.

Gastvorträge und Workshops: Unternehmen halten regelmäßig Gastvorträge und Workshops an der NORDAKADEMIE. Studierenden profitieren hierdurch von den Erfahrungen und dem Wissen der Experten.

Gemeinsame Forschungsprojekte: Kooperationsunternehmen und NORDAKADEMIE führen gemeinsame Forschungsprojekte durch. Diese umfassen Ideen für neue SAP-Lösungen, die Untersuchung aktueller Trends sowie Herausforderungen in der IT-Branche.

4. Innovation durch duale Hochschulen und SAP

Die Kombination aus dualer Ausbildung und der Integration von SAP in die Lehre kann zu zahlreichen Innovationen führen. Dies umfasst sowohl technologische als auch organisatorische Innovationen.

4.1. Technologische Innovationen

Entwicklung neuer SAP-Lösungen: Durch die enge Zusammenarbeit zwischen Hochschulen und Unternehmen können neue SAP-Lösungen entwickelt werden. Studierende bringen frische Ideen und aktuelle Forschungsergebnisse ein, die zur Weiterentwicklung der SAP-Software beitragen können.

Verbesserung bestehender Systeme: Studierende und Unternehmen können gemeinsam bestehende SAP-Systeme analysieren und Verbesserungspotenziale identifizieren. Dies kann zur Optimierung von Geschäftsprozessen und zur Steigerung der Effizienz führen.

Integration neuer Technologien: Duale Hochschulen und Unternehmen können gemeinsam neue Technologien wie Künstliche Intelligenz (KI), Machine Learning und Big Data in SAP-Systeme integrieren. Es werden neue Möglichkeiten für die Analyse und Nutzung von Daten eröffnet.

4.2. Organisatorische Innovationen

Neue Ausbildungsmodelle: Die Kombination von akademischer Ausbildung und praktischer Erfahrung kann zu neuen Ausbildungsmodellen führen. Besonders in den Fokus rückt dabei die Entwicklung von Blended-Learning-Konzepten und die Integration von Online-Lernplattformen.

Flexibilisierung der Arbeitswelt: Durch die Zusammenarbeit mit dualen Hochschulen können Unternehmen flexible Arbeitsmodelle entwickeln, die besser auf die Bedürfnisse der Mitarbeiter eingehen. So können Studium und Beruf besser miteinander vereinbart werden.

Förderung der Unternehmenskultur: Die enge Zusammenarbeit mit Hochschulen und die Integration von jungen Talenten können zur Förderung einer innovativen Unternehmenskultur beitragen. So wird ein kreatives und offenes Arbeitsumfeld geschaffen, in dem neue Ideen gefördert und umgesetzt werden können.

5. Herausforderungen und Lösungsansätze

Trotz der zahlreichen Vorteile gibt es auch Herausforderungen bei der Integration von SAP in die Lehre an dualen Hochschulen. Diese Herausforderungen können jedoch durch gezielte Maßnahmen eingegrenzt werden.

5.1. Hohe Komplexität der SAP-Software

SAP-Software ist komplex und erfordert ein tiefes Verständnis für betriebswirtschaftliche Prozesse und IT-Kenntnisse. Dies kann für Studierende eine große Herausforderung darstellen.

Lösungsansatz: Die Hochschulen können umfangreiche Schulungs- und Unterstützungsangebote bereitstellen. Dies umfasst Einführungskurse, Tutorien und die Bereitstellung von Lernmaterialien. Zudem können Unternehmen durch Gastvorträge und Workshops zur Vermittlung des erforderlichen Wissens beitragen.

5.2. Schneller technologischer Wandel

Die IT-Branche ist von einem schnellen technologischen Wandel geprägt. Dies erfordert eine kontinuierliche Anpassung der Lehrinhalte und -methoden.

Lösungsansatz: Die Hochschulen können eng mit Unternehmen und Forschungsinstituten zusammenarbeiten, um stets auf dem neuesten Stand der Technik zu bleiben. Dies umfasst die regelmäßige Überprüfung und Aktualisierung der Lehrpläne sowie die Integration aktueller Forschungsergebnisse in die Lehre.

5.3. Unterschiedliche Anforderungen von Hochschule und Unternehmen

Die Anforderungen von Hochschulen und Unternehmen können unterschiedlich sein. Dies kann zu Konflikten und Herausforderungen bei der Gestaltung der dualen Ausbildung führen.

Lösungsansatz: Eine enge Zusammenarbeit und regelmäßige Kommunikation zwischen Hochschule und Unternehmen sind entscheidend. Gemeinsame Workshops und Meetings können dazu beitragen, die unterschiedlichen Anforderungen zu identifizieren und Lösungen

zu entwickeln. Zudem können gemeinsame Forschungsprojekte und Praxisphasen zur besseren Integration der unterschiedlichen Anforderungen beitragen.

6. Fazit

Duale Hochschulen wie die NORDAKADEMIE in Elmshorn können durch die Integration von SAP in die Lehre wichtige Innovationstreiber sein. Sie bieten eine praxisnahe Ausbildung, die den direkten Wissenstransfer zwischen Hochschule und Unternehmen fördert. Dies trägt zur Entwicklung neuer SAP-Lösungen und zur Verbesserung bestehender Systeme bei. Zudem ermöglicht die enge Zusammenarbeit zwischen Hochschule und Unternehmen die frühzeitige Identifikation und Förderung von Talenten. Trotz der bestehenden Herausforderungen bieten duale Hochschulen und SAP große Potenziale für technologische und organisatorische Innovationen. Die kontinuierliche Anpassung der Lehrinhalte und -methoden sowie die enge Zusammenarbeit zwischen Hochschule und Unternehmen sind dabei entscheidend. Insgesamt kann die Integration von SAP in die Lehre an dualen Hochschulen dazu beitragen, die Innovationsfähigkeit von Unternehmen zu steigern und die Wettbewerbsfähigkeit zu sichern.

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TRACK 2: UMGANG MIT FORTSCHRITTLICHEN TECHNOLOGIEN

Track Chairs: Prof. Dr. Christian Drumm, Prof. Dr. Stefan Stöckler

Krypto-Agilität und Post-Quanten-Kryptografie: Strategien zur Sicherung digitaler Geschäftsprozesse im Quantenzeitalter

Christian Thiel
OST Ostschweizer Fachhochschule, St. Gallen, Schweiz

Abstract: Die Verschlüsselung und Signierung von Nachrichten ist eine lange etablierte Praxis, die darauf abzielt, unbefugtes Mitlesen und Manipulieren zu verhindern. Parallel zur Entwicklung der Kryptografie existiert das Bestreben, diese Schutzmechanismen zu brechen. Die bevorstehende Entwicklung von Quantencomputern stellt eine erhebliche Bedrohung für die gegenwärtig verwendeten kryptografischen Verfahren dar. Krypto-Agilität bietet einen Ansatz, um Systeme flexibel an neue Bedrohungen anzupassen. Dieses Paper untersucht die Grundlagen der Krypto-Agilität, die Bedrohungen der Kryptografie durch Quantencomputer und praktische Umsetzungsmöglichkeiten, einschließlich der Migration zu Post-Quanten-Kryptografie (PQC), mit einem besonderen Fokus auf deren Bedeutung und Anwendung im Geschäftsprozessmanagement (GPM).

Keywords: Krypto-Agilität, Post-Quanten-Kryptografie,

1. Einleitung

Die Praxis der Verschlüsselung und Signierung von Nachrichten reicht weit in die Geschichte zurück. Ebenso alt ist der Versuch, diese kryptografischen Verfahren zu brechen. Diese Dynamik hat zur Entstehung eines Wettlaufs geführt, in dem immer sicherere kryptografische Verfahren auf immer ausgefeiltere Angriffstechniken treffen. Ein Grossteil der heute auf breiter Basis eingesetzten asymmetrischen kryptografischen Verfahren kann nicht mehr als sicher betrachtet werden, sobald die Faktorisierung grosser Ganzzahlen (genauer sogenannter RSA-Moduln) und die Berechnung sogenannter diskreter Logarithmen effizient möglich ist. Peter Shor zeigte erstmals, dass beide Probleme asymptotisch effizient gelöst werden können, wenn ein hinreichend grosser und verlässlicher Quantencomputer verfügbar ist (Shor 1999). Weitere Quantenalgorithmen (Grover 1997) oder (Simon 1994) haben zudem - obgleich nicht so drastisch - Implikationen für die symmetrische Kryptografie, insbesondere auf deren Schlüssellängen und Betriebsarten. Die amerikanische National Security Agency (NSA) hat daher bereits im August 2015 vor Quantencomputern gewarnt und die Migration zu Quantencomputer-resistenten Verfahren eingeleitet (Simonite 2016). Auch aus Sicht des Bundesamts für Sicherheit in der Informationstechnik (BSI) wird Post-Quanten-Kryptografie langfristig zum Standard werden (BSI 2020).

2. Die Bedrohung

Das zugrundeliegende Prinzip, die bisher eingesetzten Public-Key-Verfahren wie z.B. RSA und ECDSA mit deutlich grösseren Schlüsseln als derzeit üblich in der Post-Quanten-Ära weiter zu verwenden, erscheint auf den ersten Blick naheliegend. Tatsächlich hat die Vorgehensweise, die Schlüsselgrössen von Rivest–Shamir–Adleman (RSA) und Elliptic Curve Digital Signature Algorithm (ECDSA) zu erhöhen, um der verbesserten Kryptoanalyse und neu entdeckten Angriffen zu begegnen, Tradition.Leider würde dieses Prinzip im Zusammenhang mit

Quantencomputern sehr schnell zu so grossen und unhandlichen, und damit nicht mehr nutzbaren, Schlüsselgrössen führen.

Post-Quanten-RSA (also RSA mit solch grossen Schlüssellängen) wurde von Bernstein untersucht, der die technische Machbarkeit der Implementierung eines Terabit-Schlüssels unter Verwendung von 2^31 4096-Bit-Primzahlen als Faktoren zeigte (Bernstein et al. 2017). Bei diesen Schlüsselgrössen benötigte jede RSA-Operation unpraktikabel viel Zeit.

Quantencomputer beruhen auf dem Konzept von Qubits (quantum bit), wobei jedes Qubit als Überlagerung der Zustände 1 und 0 und allen dazwischen liegenden Zuständen gleichzeitig existiert. Die Anzahl der stabilen Qubits, die auf einem Quantencomputer benötigt werden, um RSA zu brechen, wird auf 2n+3 (Takahashi & Kunihiro 2006) und 2n+2 (Beauregard 2002) geschätzt. Das bedeutet, dass ein Quantencomputer mit ca. 4.000 stabilen Qubits erforderlich ist, um eine RSA-2048-Signatur zu brechen. Shors Algorithmus kann ebenfalls angepasst werden, um das Problem des diskreten Logarithmus zu lösen. Die Anzahl der Qubits, um ECDSA zu brechen, beträgt „ungefähr“ 6n (Bernstein 2019). Das bedeutet, dass ein Quantencomputer mit ca. 1.500 Qubits eine Elliptic Curve Cryptography ECC-P256-Signatur brechen kann.

Folgt man der Annahme des Neven'schen Gesetzes (dem Quantenäquivalent des Moore'schen Gesetzes), kann man schätzen, dass die Rechenleistung von Quantencomputern gegenüber klassischen Computern mit einer „doppelt exponentiellen Rate“ zunimmt (Hartnett 2019). Wenn wir in einem bestimmten Jahr mit 100 Qubits beginnen und die Qubits alle 18 Monate verdoppeln, werden wir neun Jahre später wahrscheinlich Computer mit über 6.000 Qubits haben und in 32 Jahren in der Lage sein, einen RSA-Schlüssel mit einer Million Bit zu brechen.

Der aktuelle Stand der Quantencomputing-Technologie zeigt bedeutende Fortschritte, insbesondere bei der Entwicklung von leistungsfähigeren und stabileren Qubits. IBM hat beispielsweise den Osprey-Quantencomputer mit 433 Qubits vorgestellt (Maushart 2022) und plant, innerhalb der nächsten zehn Jahre einen Quantencomputer mit 100.000 Qubits zu entwickeln. Diese Fortschritte zeigen, dass Quantencomputer immer näher an die Fähigkeit herankommen, praktische und komplexe Probleme zu lösen, die für klassische Computer nicht erreichbar sind.

Ein bedeutendes Ziel der Quantencomputing-Forschung ist die Überwindung der aktuellen Einschränkungen durch fehlerkorrigierte logische Qubits, die stabiler und zuverlässiger sind als die bisherigen physischen Qubits. Diese Entwicklung wird voraussichtlich in den kommenden Jahren erfolgen und markiert einen wichtigen Schritt in Richtung leistungsfähigerer Quantenberechnungen. Aktuelle Modelle und Algorithmen, wie Shors Algorithmus, zeigen theoretisch, dass ein Quantencomputer mit etwa 20 Millionen physischen Qubits erforderlich wäre, um einen 2048-Bit-RSA-Schlüssel zu brechen (Gidney & Ekerå 2019). Diese Zahl berücksichtigt die Notwendigkeit der Fehlerkorrektur und die derzeitigen Fehlerquoten bei Qubits. Es wird erwartet, dass Quantencomputer in etwa 10 bis 15 Jahren eine signifikante Bedrohung für aktuelle Verschlüsselungstechnologien darstellen könnten. Daher ist die Forschung und Entwicklung in post-quantensicherer Kryptographie von entscheidender Bedeutung, um zukünftige Sicherheitsbedrohungen zu mindern.

3. Verfahren

3.1. Übersicht zu PQC-Verfahren

Aufgrund der oben genannten Betrachtungen scheiden klassische Kryptoverfahren wie RSA und ECDSA (Elliptic Curve Digital Signature Algorithm) mit sehr grossen Schlüsseln mittelfristig aus und können allenfalls für eine kurze Übergangsphase genutzt werden. Quantenerweiterte Verfahren spielen nach aktuellem Forschungsstand speziell für elektronische Signaturen (noch) keine Rolle. Mittel- und langfristig sollte man sich also auf PQC-Verfahren konzentrieren. Unter PQC-Verfahren verstehen wir in dieser Studie Kryptoverfahren (im speziellen asymmetrische Kryptoverfahren), die nach aktuellem Stand der Forschung möglicherweise ausreichende Sicherheit gegen Angriffe, die die Fähigkeiten und Eigenschaften von Quantencomputern nutzen, bieten können. Die bisher in der Literatur und Forschung betrachteten Quantencomputer-resistenten asymmetrischen kryptographischen Verfahren lassen sich aktuell in fünf Familien basierend auf den Sicherheitsannahmen zugrunde liegenden mathematischen Problemen einteilen:

- Gitterbasierte Verfahren, bei denen die Sicherheit von der Schwierigkeit abhängt, ein kurzes oder nächstes Vektorproblem in einem Gitter zu lösen.
- Multivariate Primitive, bei denen die Sicherheit von der Schwierigkeit abhängt, ein System von multivariaten Polynomgleichungen zu lösen.
- Code-basierte Primitive, bei denen die Sicherheit von der Schwierigkeit abhängt, ein Dekodierungsproblem in einem linearen Code zu lösen.
- Hash-basierte Primitive, bei denen die Sicherheit von der Schwierigkeit abhängt, Kollisionen oder Urbilder in kryptografischen Hash-Funktionen zu finden.
- Isogenie-basierte Schlüsselprimitive, bei denen die Sicherheit davon abhängt, wie schwierig es ist, eine unbekannte Isogenie zwischen einem Paar übersingulärer elliptischer Kurven zu finden.

3.2. Standardisierung

Das National Institute of Standards and Technology (Chen et al. 2016) hat einen Standardisierungsprozess für quantensichere Kryptographie initiiert, um die Entwicklung von Verfahren zu fördern, die gegen Angriffe von Quantencomputern resistent sind. 2022 wurden die ersten vier Algorithmen ausgewählt: CRYSTALS-Kyber für die allgemeine Verschlüsselung sowie CRYSTALS-Dilithium, FALCON und SPHINCS+ für digitale Signaturen (NIST 2022). Diese Algorithmen befinden sich derzeit in der Standardisierungsphase und sollen bis 2024 einsatzbereit sein. Im August 2023 veröffentlichte das National Institute of Standards and Technology (NIST) Entwürfe für drei dieser Algorithmen und sammelt Rückmeldungen von der internationalen Kryptographie-Community. Der Entwurf für den vierten Algorithmus, FALCON, wird 2024 erwartet (NIST 2023). Zusätzlich werden weitere Algorithmen wie BIKE, HQC und SIKE in einer vierten Bewertungsrunde untersucht, um alternative Lösungen zu bieten. Neben den Bemühungen von NIST gibt es weltweit weitere Initiativen zur Standardisierung post-quantenkryptographischer Algorithmen, z.B. hat das Europäische Institut für Telekommunikationsnormen (ETSI) die ETSI Quantum-Safe Cryptography (QSC) working group eingerichtet, die technische Spezifikationen und Whitepapers zur quantensicheren Kryptographie veröffentlicht hat. Die Cybersecurity and Infrastructure Security Agency (CISA) hat eine entsprechende Initiative gestartet und arbeitet dabei eng mit NIST zusammen.

4. Migration

Post-Quanten-Kryptografie wird langfristig zum Standard werden. Abhängig vom Anwendungsfall sollte aber frühzeitig im Rahmen eines massvollen Risikomanagements abgewogen werden, ob und wann ein Umstieg auf Quantencomputer-resistente Verfahren erfolgen sollte. Für kryptografische Anwendungen, die Informationen mit langen Geheimhaltungsfristen und hohem Schutzbedarf verarbeiten, ergibt sich gegebenenfalls jetzt schon Handlungsbedarf. Hier besteht die Gefahr, dass Nachrichten zur Schlüsselaushandlung und die mit den ausgehandelten Schlüsseln verschlüsselten Daten auf Vorrat gesammelt und in der Zukunft mit Hilfe eines Quantencomputers entschlüsselt werden („store now decrypt later"). Auch bei sehr langen Gültigkeitszeiten für Signaturschlüssel ist Vorsicht geboten. Es muss also bereits jetzt diskutiert werden, wie eine Migration auf Post-Quanten-Kryptografie für Hersteller und Anwender zu einem vollständig quantensicheren kryptographischen Zustand (Fully Quantum Safe Cryptographic State FQSCS) schon heute eingeleitet werden kann. Ein Migrationsrahmen und der Migrationsplan, der ihn dokumentiert, umfasst wie bei jeder Art von Migration die folgenden drei Stufen:

Eine gründliche Inventur der eingesetzten Kryptographietechnologien ist notwendig, um die Dringlichkeit der Migration zu PQC zu verstehen und zu priorisieren. Dies schliesst die Identifikation von Systemen ein, die gegenwärtig auf quantenanfällige Kryptografie angewiesen sind. Diese Inventur sollte ein umfassendes Verständnis darüber vermitteln, welche kryptografischen Algorithmen in den aktuellen IT- und OT-Systemen verwendet werden, wie diese aufgerufen werden und welche kryptografischen Algorithmen verwendet werden. In Unternehmen wird Kryptografie vielseitig eingesetzt, um die Sicherheit und Integrität von Daten in Geschäftsprozessen zu gewährleisten. E-Mail-Verschlüsselung und VPNs sichern die Kommunikation, während Daten sowohl im Ruhezustand als auch während der Übertragung verschlüsselt werden. Digitale Signaturen und Multi-Faktor-Authentifizierung dienen der Authentifizierung und Zugriffskontrolle. Im E-Commerce und bei Blockchain-Technologien sorgt Kryptografie für sichere Transaktionen. Software und geistiges Eigentum werden durch Code-Signing und Rechtemanagement geschützt, während leichte kryptografische Algorithmen die Kommunikation in IoT-Geräten sichern. Zusätzlich sollte geklärt und dokumentiert sein, wer für welche Teile des Systems verantwortlich ist und wie diese aktualisiert werden können.

Der Migrationsplan sollte die Erstellung einer Quantum-Readiness Roadmap umfassen. Diese hilft, die notwendigen Schritte zur Migration auf PQC zu definieren und zu koordinieren. Dazu gehört auch die Schulung von IT-Personal und die Anpassung von Geschäftsprozessen, um die Integration zu unterstützen. Die Roadmap sollte auch die Zusammenarbeit mit Technologieanbietern beinhalten, um deren Pläne zur Implementierung von PQC zu verstehen und sicherzustellen, dass neue Produkte und Systemaktualisierungen PQC unterstützen werden. Die tatsächliche Implementierung der PQC-Verfahren in den identifizierten Systemen und Prozessen sollte in enger Zusammenarbeit mit den entsprechenden Technologieanbietern und internen Stakeholdern erfolgen. Dies umfasst die Implementierung neuer kryptografischer Algorithmen, die Durchführung umfangreicher Tests zur Sicherstellung der Kompatibilität und Sicherheit sowie die kontinuierliche Überwachung und Anpassung der Systeme, um auf neue Bedrohungen und Entwicklungen reagieren zu können.

5. Zwischenschritte

Für die Zwischenschritte werden dazu in (BSI 2020) verschiedene Massnahmen aufgezeigt: Bei der Neu- und Weiterentwicklung von Anwendungen sollte vor darauf geachtet werden, die kryptografischen Mechanismen möglichst flexibel zu gestalten, um auf alle denkbaren Entwicklungen reagieren, kommende Empfehlungen und Standards umsetzen und möglicherweise in Zukunft Algorithmen, die nicht mehr das gewünschte Sicherheitsniveau garantieren, austauschen zu können („Kryptoagilität"). Dies gilt insbesondere aufgrund der Bedrohung durch Quantencomputer – aber nicht ausschliesslich: Auch klassische Angriffe können sich weiterentwickeln und einstmals als sicher eingestufte Verschlüsselungsverfahren oder Schlüssellängen obsolet machen. Zustandsbehaftete hashbasierte Signaturverfahren haben gewisse Nachteile. So können mit ihnen nur eine im Vorhinein begrenzte Anzahl von Signaturen geleistet werden. Sie eignen sich aber insbesondere für die Signatur von Firmware-Updates oder Code Signing, da hierfür z.B. nur eine geringe Zahl von Signaturen erforderlich ist. Der Einsatz von zustandsbehafteten hashbasierten Signaturverfahren wird schon seit Längerem vom BSI empfohlen (BSI 2013).

Auch wenn der Fokus dieses Textes auf asymmetrischen Verfahren liegt und symmetrische Verschlüsselungsalgorithmen wesentlich weniger durch die Entwicklung von Quantencomputern bedroht sind als asymmetrische Verfahren, sollte bei Schlüsseltransportverfahren etc. doch beachtet werden, dass bei Verwendung von Schlüsseln mit einer Länge von 128 Bit (oder weniger) Quantencomputer-Angriffe mit dem Suchalgorithmus von Grover möglich sind. Insbesondere, wenn es auf einen langfristigen Schutz von Daten ankommt, sollte daher bei Neuentwicklungen, bei denen ein symmetrischer Verschlüsselungs-algorithmus implementiert werden soll, eine Schlüssellänge von 256 Bit vorgesehen werden.

Meist wird asymmetrische Kryptografie benötigt, um ein gemeinsames Geheimnis zwischen den Kommunikationspartnern auszutauschen, aus dem dann symmetrische Sitzungsschlüssel abgeleitet werden. Als kurzfristige Schutzmassnahme gegen Angriffe mit Quantencomputern kann für die Schlüsselableitung zusätzlich ein vorverteilter symmetrischer Langzeitschlüssel verwendet werden. Ebenso ist es möglich, einen asymmetrischen Schlüsselaustausch mit Hilfe eines vorverteilten Geheimnisses symmetrisch zu verschlüsseln. In beiden Fällen muss jeweils das Problem der Verteilung der symmetrischen Langzeitschlüssel gelöst werden.

Die Quantencomputer-resistenten Verfahren, die zurzeit standardisiert werden, sind noch nicht so gut erforscht wie die „klassischen" Verfahren (RSA und ECC). Dies gilt insbesondere mit Hinblick auf Schwächen, die sich grösstenteils erst in der Anwendung zeigen wie typische Implementierungsfehler, mögliche Seitenkanalangriffe, usw. Das BSI empfiehlt daher, Post-Quanten-Kryptografie möglichst nicht isoliert einzusetzen, sondern „hybrid" in Kombination mit klassischen Algorithmen. Bei einem hybriden Schlüsselaustausch müssen dafür beispielsweise die beiden ausgehandelten Geheimnisse mittels einer geeigneten Schlüsselableitungsfunktion zu einem Sitzungsschlüssel kombiniert werden. Der Umstieg auf Quantencomputer-resistente Verfahren, insbesondere der Einsatz von hybriden Lösungen, erfordert Anpassungen in den heute verwendeten kryptografischen Protokollen. Für die Protokolle Transport Layer Security (TLS) und Internet Key Exchange (IKEv2) gibt es bereits Ansätze dafür, siehe z.B. (IETF 2015). Diese Anpassungen erfolgen unabhängig von der konkreten Auswahl von Quantencomputer-resistenten Verfahren. Zurzeit gibt es aufgrund des Ressourcenbedarfs bestehender PQC-Verfahren für einzelne Anwendungen, die auf der

Nutzung von Smartcards oder anderen Devices beruhen, keine befriedigende Alternative zu RSA oder ECC. Es kann jedoch erwartet werden, dass diese Verfahren weiterentwickelt und optimiert werden. Der Handlungsbedarf bei Schlüsseleinigungsverfahren ist deutlich grösser als bei Signaturverfahren. Für eine Schlüsseleinigung sind das gitterbasierte Verfahren FrodoKEM und das codebasierte Verfahren Classic McEliece die aus Sicht des BSI konservativste Wahl (BSI 2024).

6. Umsetzung von Krypto-Agilität im Geschäftsprozessmanagement

Für eine erfolgreiche Umsetzung von Krypto-Agilität müssen mehrere organisatorische und technische Bereiche nahtlos zusammenarbeiten. Krypto-Agilität bedeutet, dass Systeme und Prozesse flexibel und anpassungsfähig sind, um schnell auf neue Bedrohungen und Entwicklungen reagieren zu können. Dies betrifft auch das Geschäftsprozessmanagement (GPM), da Geschäftsprozesse kontinuierlich überwacht, angepasst und optimiert werden müssen, um ihre Effizienz und Sicherheit zu gewährleisten. Organisationen sollten fundiertes Wissen über aktuelle kryptografische Verfahren und ihre Alternativen besitzen. Es sollte Wissen zu verschiedenen heute verwendeten kryptografischen Verfahren und Alternativen, auch der Post-Quanten-Kryptografie, verfügbar sein. Ebenso sollte theoretisches und praktisches Wissen zu Krypto-Agilität und ihrer Umsetzung vorhanden sein. Dieses Wissen ermöglicht es der Organisation, fundierte Entscheidungen im Bereich der Kryptografie zu treffen. Es muss geklärt, bekannt und dokumentiert sein, wer für welche Teile des Systems verantwortlich ist, wie sie aktualisiert werden können und welche Zugänge dafür notwendig sind. Es sollte bekannt sein, wo Kryptografie in den Geschäftsprozessen eingesetzt wird oder zukünftig eingesetzt werden soll, wie diese aufgerufen wird und welche kryptografischen Algorithmen verwendet werden. In der Einrichtung sollte es ein zentrales Gremium geben, das Entscheidungen zur IT-Sicherheit treffen kann. Dieses Gremium arbeitet anhand von Guidelines, zum Beispiel vom BSI, die festlegen, welche kryptografischen Verfahren genutzt werden. Es sollten Prozesse für Updates existieren, die umfangreiches Testen beinhalten. Entscheidungsprozesse sind so aufgebaut, dass sie agiles Handeln in der Kryptografie unterstützen und somit die Integrität der Geschäftsprozesse gewährleisten.

Die Hardware sollte modular aufgebaut sein. Komponenten sollten ohne grossen Aufwand ausgetauscht werden können. Insbesondere sollten Hard- und Software unabhängig voneinander austauschbar sein. Alle Bestandteile des Systems sollten genügend Puffer für komplexere Berechnungen und grössere Schlüssel, verschlüsselte Nachrichten und Signaturen haben. Im System sind genügend Kapazitäten für die Nutzung anderer kryptografischer Verfahren vorhanden – auch quantenresistenter Verfahren, was die Kontinuität der Geschäftsprozesse sicherstellt. Die Software sollte modular aufgebaut sein. Einzelne Komponenten sollten ohne grossen Aufwand ausgetauscht werden können. Kryptografie sollte über abstrakte Schnittstellen genutzt werden. Es sollte möglich sein, unkompliziert kryptografische Algorithmen hinzuzufügen und zu entfernen. Es stehen softwareseitig verschiedene kryptografische Algorithmen zur Verfügung, die flexibel genutzt werden können, um die Sicherheit der Geschäftsprozesse zu gewährleisten, indem sie die Vertraulichkeit, Integrität und Authentizität von Daten und Kommunikationskanälen gewährleisten.

7. Fazit

Krypto-Agilität und die Migration zu Post-Quanten-Kryptografie sind entscheidende Schritte, um die Sicherheit digitaler Geschäftsprozesse im Quantenzeitalter zu gewährleisten. Durch flexible und anpassungsfähige kryptografische Systeme können Organisationen schnell auf neue Bedrohungen reagieren und die Integrität und Sicherheit ihrer Geschäftsprozesse aufrechterhalten.

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Nachhaltigkeit im Immobilienwesen

Alexander Redlein, Eva Stopajnik
Technische Universität Wien

Abstract: Nachhaltigkeit hat in den letzten Jahren stark an Bedeutung gewonnen. Dies wurde nicht nur durch die Konsumenten getrieben, sondern auch durch diverse Gesetzgebungen, wie die EU Taxonomie, die CSRD und ESRS der EU. Diese fordern unter anderem im Bereich der nichtfinanziellen Berichtserstattung von Unternehmen gesicherte Informationen über deren Energieverbrauch und den CO2 Fußabdruck. Damit aber nicht genug, es wird auch gefordert, dass Unternehmen bis 2050 CO2 neutral agieren und die notwendigen Maßnahmen in diesen Berichten dokumentieren. Das IFM der TU Wien beschäftigt sich nun seit über 15 Jahren mit dem Thema Nachhaltigkeit vor allem im Bereich Immobilien, da sie für rund 40% des CO2 Ausstoßes weltweit verantwortlich sind. Im Rahmen des seit dem Jahr 2010 verwendeten Curriculums werden die Regelungen im Bereich Nachhaltigkeit und Raumklima sowie Arbeitnehmerschutz dargestellt. Dann wird gezeigt wie sich Liegenschaften und Gebäude in SAP abbilden lassen und auch Messwerte über Medienverbräuche wie Strom und Wasser abbilden lassen. Anhand der Messwerte wird den Student:innen gezeigt, wie sie Anomalien und Großverbraucher erkennen können und welche Maßnahmen geeignet sind, den CO^2 Abdruck zu verbessern. Im ersten Szenario wird ein nicht effizienter Kühlturm analysiert und dann ausgetauscht. Im zweiten Szenario wird durch präventive Wartungsmaßnahmen wie Filterreinigung und Tausch die Effizienz, aber auch die Lebensdauer optimiert. Aktuell wurde es auch ermöglicht, Energiedaten und Raumklimaparameter von IoT Messgeräten online in die Messreihen zu übernehmen, um so noch praxisnahe die Analyse der Anlagen zu ermöglichen.

Empowering Citizen Developers: The Crucial Role of Effective Governance

G.-L. Gücük[1], D. Simic[1], S. Leible[1], C. von Brackel-Schmidt[1] & S. Schlager[2]
[1]University of Hamburg, Hamburg, Germany
[2]Offenburg University of Applied Sciences, Offenburg, Germany

Abstract: The emergence of low-code and no-code platforms (LNCPs) has led organizations to increasingly employ so-called citizen developers (CDs), empowering ordinary employees, commonly business employees or domain experts, to develop their own software applications. However, this integration poses significant risks. Unrestricted access to software development by CDs can result in the emergence of shadow IT, IT security issues, and the lack of quality in software applications across the organization. Proper governance mechanisms for LNCPs and CDs can mitigate these risks, preventing the creation of shadow IT and maintaining transparency. Given the scarcity of research on such mechanisms, we conducted an integrative literature review and expanded our findings with practical frameworks proposed by incumbent organizations. We synthesized four recommendations based on ten identified best practices and eight pitfalls. Our findings provide guidance for practitioners aiming to develop and integrate governance frameworks for LNCPs and CDs, achieving a secure and transparent application ecosystem.

Keywords: citizen developer, governance, low-code, no-code, integration

1. Introduction

In recent years, the demand for employees proficient in low-code and no-code platforms (LNCPs) has steadily increased (Binzer & Winkler 2023). Particularly for so-called citizen developers (CDs), employees who are neither part of the IT department nor professional programmers, LNCPs enable the creation of business applications for organizational use (Lebens et al. 2021). CDs are especially well-suited for this role due to their expertise in their respective departments, which grants them an intimate understanding of processes and shortcomings (Käss et al. 2022). They can foster employee-driven innovations (Leible et al. 2024b) by driving bottom-up development, thereby reducing dependence on IT and other departments for specialized knowledge. LNCPs are predominantly offered as platform-as-a-service models, allowing for easy deployments within organizations and application modeling via a drag-and-drop graphical user interface (Rymer 2017). Widely used platforms in this sector include OutSystems, Appian, and Microsoft PowerApps, which are among the best-rated by Gartner (Gartner 2024). Recently, SAP also entered the LNCP market with the release of SAP Build Code (Nainani 2024).

The rise of CDs can be attributed to a shortage of IT talent and increased demand for IT units (Binzer & Winkler 2022). However, integrating CDs into an organization's software development processes can elevate security, compliance, and privacy risks (Käss et al. 2022). Additionally, there is an inherent threat of creating a shadow IT, where CDs develop (new) applications that are unknown to and unsupported by the IT department. This lack of transparency hinders monitoring and can lead to significant IT security issues (Deloitte 2021). These risks stem from unclear responsibilities and boundaries between CDs and the IT

department, which is responsible for operating the organization's software infrastructure (Heuer et al. 2022).

To mitigate the risks associated with developing applications using LNCPs, it is essential to establish clearly defined governance rules that support sustainable resource use and data security (Callinan & Perry 2024). These rules help to prevent potential IT compromises, avoid shadow IT, ensure data integrity and transparency, and manage the software lifecycle (Heuer et al. 2022). This leads to the research question (RQ) addressed in this paper: *What are good practices for governing citizen developers in organizations, and what pitfalls can arise from neglecting them?*

Our paper offers guidance to practitioners on developing governance for the integration and use of LNCPs with CDs by outlining good practices and identifying potential pitfalls. We conducted an integrative literature review (Torraco 2016) and derived recommendations based on our findings regarding LNCP governance in organizations.

2. Low-Code, No-Code, and Citizen Development

Although we group low-code (LC) and no-code (NC) platforms under a single term – LNCPs, we do not consider their functionalities equivalent. A significant portion of the literature uses these terms synonymously, which is a strong simplification (e.g., Binzer & Winkler 2023; Käss et al. 2022). According to SAP, the primary difference between NC and LC lies in the required coding knowledge: LC requires basic coding skills, whereas NC requires none (SAP 2024). Given the capabilities of generative AI (Leible et al. 2024a), LNCP providers have begun to incorporate this technology into their platforms to enhance functionality and further simplify coding.

CDs have emerged as a significant research topic in recent years (Binzer & Winkler 2023; McKendrick 2017; Lebens et al. 2021). SAP describes them as "*subject-area specialists*" with unique knowledge that is challenging to convey to IT teams (SAP 2024). In scientific literature, CDs are similarly defined as employees who are neither part of the IT department nor professional programmers but are enabled through the use of LNCPs to create software applications within an organization (Lebens et al. 2021). Due to a significant shortage of IT experts, the demand for CDs is steadily increasing (Binzer & Winkler 2022). However, employing CDs poses risks, such as IT security issues, lack of transparency, and the development of shadow IT, particularly if individuals are not adequately trained and guided and the organization lacks appropriate preparations and conditions. These substantial risks underscore the importance of establishing effective governance to successfully integrate and establish CDs (McKendrick 2017).

3. Method

We conducted an integrative literature review (Torraco 2016) to examine good practices and experiences with LNCPs and CDs documented in the literature. The aim was to establish a foundation for deriving governance mechanisms and recommendations. To achieve this, we collected a diverse array of conference papers and journal articles using Google Scholar in May 2024. Google Scholar was chosen as it indexes various literature databases, providing a quick overview of research on LNCPs and CDs across different domains, thereby laying the

groundwork for addressing our research question (RQ). Two search strings were established to focus on the scope of this paper: (1) *((low-code platform OR no-code platform) AND governance)* and (2) *("citizen developer" AND governance)*. We sorted the search results based on their relevance to the search strings. After a preliminary screening of the titles and abstracts of the results, we selected 20 papers for a comprehensive full-text analysis.

The full-text analysis involved several criteria for deciding whether a paper was included or excluded from the final dataset. We included papers that were directly relevant to the subjects of LNCPs and CDs and addressed governance aspects. This process enabled us to select and analyze the most pertinent literature, resulting in nine papers for the final dataset. The literature provided insights into LNCP and CD governance and highlighted risks associated with inadequate or absent governance. During our coding process, we categorized the content inductively based on thematic relevance, including governance aspects and mechanisms, pitfalls, and good practices. Additionally, we enriched our dataset with exemplary practical governance frameworks from the organizations SAP, Deloitte, and Hitachi Solutions. This approach allowed us to extract and synthesize key themes and findings, ultimately deriving recommendations for practical application.

4. Results

4.1. Practical Frameworks

SAP has recently intensified its efforts in the LNCP market by unveiling SAP Build Code (Nainani 2024). In a blog entry from 2023, a former vice president of SAP emphasized the necessity of governance for such platforms within organizations (Schroetel 2023). He outlines five potential governance models, ranging from high trust and autonomy to high control and monitoring.

(1) The first model is *Trust-based*, which involves high risk but aims to maintain trust and control. It primarily focuses on LNCP utilization for personal productivity application development rather than enterprise-scale processes. (2) The second model is *Guided development*, which emphasizes collaboration between business stakeholders and less stringent IT control. This model provides for e-learning opportunities and a development checklist to ensure the quality of the resulting applications. (3) The third model, *Power users enabled-to-build*, targets CDs with greater technical knowledge, providing power user training through learning sprints and hands-on tasks. In this model, users handle all development processes while IT performs final checks and deployment to production. (4) The fourth model, *Certified development*, involves more rigorous risk management, with IT defining learning requirements, basic skills, and certifications before CDs can commence. CDs here manage everything except production deployment, monitoring, and lifecycle management, which are still handled by IT. (5) The final model is *Controlled*, where strict control is maintained over all applications resulting from LNCPs and CDs. Business process owners must approve application ideas, and collaboration with IT is mandatory. CDs manage the process until deployment, which is then taken over by IT with a quality control process.

Deloitte underscores the advantages of CDs and LNCPs, emphasizing that proper governance structures are essential for avoiding poor design and pitfalls such as high dependency on individuals, inadequate change management, and insufficient data control mechanisms (Deloitte 2021). They highlight that bad or absent governance impedes transparency within the

application environment, thereby increasing operational risks related to the technical infrastructure and shadow IT. Deloitte also asserts that it is imperative for CDs to be familiar with software development fundamentals that involve training before they begin working with LNCPs.

Hitachi Solutions recognizes LNCPs as a lasting topic and underlines the importance of considering governance as a critical aspect from the outset (Hitachi Solutions 2022). They stress that implementing governance for LNCPs is essential for ensuring security, maintaining data integrity, and promoting responsible use of the platform's components. Additionally, they recommend establishing multiple environments for testing the platforms and applications resulting from them. The first environment serves as a playground for new learners, featuring data policies that prohibit the use of any live data. The second environment is designated for experienced users to create non-critical applications. The final environment should facilitate the creation of mission-critical applications for IT professionals or super users, with stringent data protection measures and rigorous governance by the IT department.

4.2. Good Practices

The scientific literature concurs with the practical insights analyzed in the previous subchapter regarding the importance of governance mechanisms for CDs and LNCPs and outlines actions for their successful implementation. One action is establishing principles for managing the data strategy within the chosen LNCPs (Heuer et al. 2022; Binzer & Winkler 2022). Since defining these principles is inherently dynamic, it requires multiple iterations to align the strategy with the organization's short- and long-term needs (Callinan & Perry 2024). Another action could be to create dedicated development zones for CDs, segregating critical from non-critical applications (Hoogsteen & Borgman 2022). This approach mitigates the risk of interfering with the production system and provides a virtual space for CDs to enhance their skills and knowledge. Additionally, as Heuer et al. (2022) state, it is imperative to clarify the responsibilities for resulting applications and delineate how CDs are supported during the development process.

Responsibilities can be managed by holding CDs accountable for their applications' quality or by having the IT department conduct quality controls, as outlined in SAP's governance models in the previous subchapter. CD support can be facilitated through enhanced and intensified communication between CDs and IT (Iho et al. 2021). However, some literature recommends that the IT department should ultimately ensure the quality of applications (e.g., Callinan & Perry 2024). This would result in a centralized governance approach where the IT department warrants compliance with technical requirements such as security, performance, and regulatory compliance (Binzer & Winkler 2022; Hoogsteen & Borgman 2022). CDs should always be motivated to strive for the best possible technical implementation. Thereby, guidelines or checklists can help them to improve application quality and reduce the burden on the IT department (Heuer et al. 2022).

4.3. Pitfalls

One of the major obstacles to integrating CD in an organization is the absence of or inadequate governance (McKendrick 2017), which can lead to several pitfalls. These pitfalls stem from the circumstance that CDs, without proper guidance, processes, and frameworks, are hindered by the lack of clearly defined responsibilities and roles across all organizational levels (Prinz et al. 2021). This encompasses micro-level decisions, such as user interface design, and macro-level

decisions, like embedding standards for the application architecture. The absence of governance can furthermore lead to an overflow of unnecessary applications.

Moreover, a lack of governance can result in the development of risky applications due to the absence of established development standards, leading to further integration issues. These applications may be inefficient (Carroll et al. 2021) or fail to meet technical requirements such as data security (Hoogsteen & Borgman 2022). Consequently, the IT department may become overwhelmed when tasked with acting as a quality gate or fixing occurring problems, leading to increased maintenance efforts (Smith et al. 2020). This situation forces the IT department to supervise CDs and their applications instead of advancing other, more critical tasks. Moreover, Iho et al. (2021) assert from a collaborative perspective that the benefits of LNCPs may remain confined to a single department in the absence of guided communication between CDs, teams, and the IT department, thereby limiting the organization's potential for innovation.

4.4. Recommendations for NLCP and CD Governance

Ten distinct good practices and eight pitfalls have been identified from the literature presented in the previous subchapters. These have been consolidated in Fig. 1 and form the foundation of the derived four overarching recommendations: (1) *define roles and responsibilities*, (2) *enhance quality management*, (3) *involve the IT department*, and (4) *establish a comprehensive strategy*.

The first recommendation is to *define roles and responsibilities*, focusing on the work processes involving CDs. An organization should specify responsibilities and outline who oversees what actions, thereby creating a shared understanding of accountability, with communication being a crucial indicator of success. If this topic is not addressed, it is likely that a small group or single individuals will possess all the knowledge and skills, leading to dependencies on specific persons and slowing down the overall development process. Furthermore, undefined roles and responsibilities make it difficult for CDs to develop meaningful applications, making it unclear whom to approach for advice or support. Consequently, cross-departmental communication and collaboration will be hindered, with each business unit creating applications in isolation.

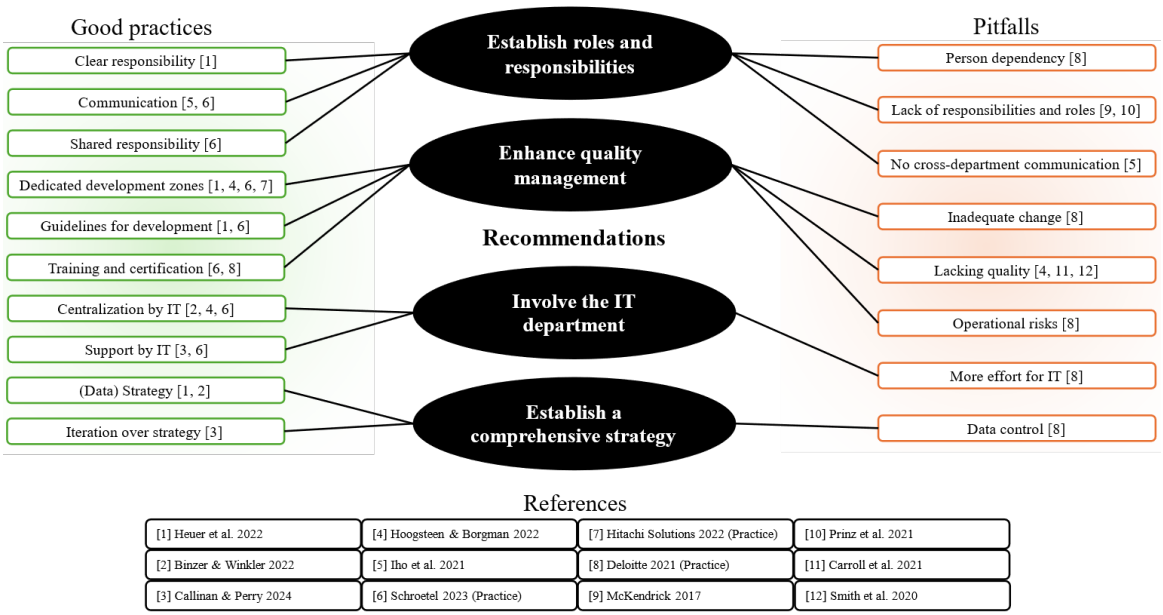

Fig. 1: Derived recommendations for NLCP and CD governance.

The second recommendation is to *enhance quality management*, which involves implementing decisions and practices that ensure high quality in developed applications. This can be achieved, for example, by creating dedicated development zones where CDs can test their applications and improve their skills without interfering with live data. Such zones can also be used to share applications and foster collaboration. Additionally, guidelines or checklists for application development are valuable, as CDs do not possess the level of technical expertise of IT department experts. Moreover, training programs can be instrumental in achieving quality standards.

The third recommendation is to *involve the IT department* when integrating CDs within an organization. Centralizing LNCPs under the oversight of the IT department is favorable, as it ensures that the IT, with its knowledge of the technical infrastructure, is responsible for controlling, maintaining, and operating the applications in the live environment. Additionally, the IT department can serve as a teaching unit for CDs. While this approach increases the workload for the IT department, it ensures adherence to standards and compliance with security regulations. Finding the right balance between oversight and autonomy of CDs can be challenging.

The final recommendation emphasizes *establishing a comprehensive strategy* for integrating CDs in the organizational software development process with LNCPs. Such a strategy should include high-level objectives and clear guidelines for data management and controlling the emerging ecosystem of new applications. Additionally, it should outline the long-term goals that the organization aims to achieve with LNCPs and CDs, ensuring alignment across all stakeholders. Given the dynamic nature of this process, frequent iterations are required to keep the strategy up to date, as both requirements and objectives may evolve over time.

5. Discussion and Conclusion

To address our RQ on LNCP and CD governance in organizations, we presented recommendations along with related good practices and pitfalls to consider when integrating and establishing such an ecosystem. We analyzed current scientific literature and examined practical frameworks published by SAP, Hitachi Solutions, and Deloitte.

As McKendrick (2017) noted, missing or bad governance is a significant obstacle to employing LNCPs and CDs successfully. Consequently, many organizations have engaged in determining the necessary elements of such governance, as evidenced by the practical frameworks found (Deloitte 2021; Hitachi Solutions 2022; Schroetel 2023). These frameworks describe approaches for governing LNCPs and CDs; however, several good practices and pitfalls highlighted in our recommendations were not included. Therefore, we provide a consolidated view of research and established organizational approaches, as depicted in Fig. 1. These insights can assist practitioners in integrating and building a viable ecosystem with LNCPs and CDs.

Our research is not without limitations. An integrative literature review is generally less comprehensive than a systematic one, so relevant papers could be missing. Additionally, the lack of a structured approach for collecting practical frameworks may have resulted in omitting other pertinent cases. Nevertheless, the dataset of literature and practical frameworks enabled us to derive a set of recommendations that can be tailored to different organizational contexts.

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Identifying Inherent Success Factors of Digital Products in Production and Logistics

Y. Langer, J. Mall & C. Sandbrink
Heilbronn University, Heilbronn, Germany

Abstract: This work analyzes the inherent success factors of digital products in different industries, with a focus on production and logistics. Through a systematic literature review, these success factors are identified and categorized, highlighting their importance for improving operational efficiency and competitive advantage in the digitalized economic landscape. By applying these findings to the field of production and logistics, the work pro-vides implications for organizations looking to innovate and succeed with digital products. This comprehensive analysis not only advances the cur-rent state of knowledge, but also lays the foundation for future research to emphasize the need for innovative and evidence-based strategies for the development and management of digital offerings.

Keywords: Digital Products, Digital Products Success Factors, Production and Logistics, Literature Review.

1. Introduction

In today's digitized economic landscape, the development and implementation of digital products has become a key factor for innovation, operational efficiency and competitive advantage in numerous industries (Royston 2019). This indicates the need for companies to adapt digital products in order to secure and expand their market position. Especially in production and logistics, where precision and efficiency are crucial, digital solutions can increase performance and lead to significant competitive advantages (Zangiacomi et al. 2020). However, companies are faced with the challenge of identifying and implementing those products from a wide range of digital innovations that are not only technologically advanced but also offer real added value (Sjödin et al. 2018). The central problem is that there is a lack of systematic identification and analysis of the inherent success factors of digital products. Research has not yet provided a comprehensive and cross-industry view of these factors, particularly in relation to production and logistics. This research gap makes it difficult for companies to develop evidence-based strategies for the selection and development of digital products that are proven to lead to success.

Given the growing relevance of digital products, it is crucial to identify the factors that determine their success. This is important not only for advancing the state of knowledge, but also to provide practical guidance for the design and implementation of effective digital solutions in production and logistics. This paper aims to help close this research gap and pave the way for further research in this important field. To solve the presented problem, the following research question and sub-questions are created:

" Which crucial factors for the success of digital products can be found in the literature?”

Q1: How can these factors be categorized?

Q2: How can these factors be applied to the area of production and logistics?

The objective of this paper is to identify and analyze the success factors of digital products in general through a comprehensive literature review. The goal is to develop an in-depth understanding of the specific characteristics that make digital products successful. Additionally, by transferring the findings to the field of production and logistics, practical implications can be derived. By compiling the current state of research, the aim is to raise awareness of the importance of these success factors and lay the foundation for future research in this area.

2. Theoretical Background - Digital Products in Production / Logistics

Digital products in production and logistics play a decisive role in the efficiency, transparency and adaptability of companies in the modern economy. Digitalization enables the optimization of material and information flows, which leads to an increase in productivity and a reduction in operating costs. One of the main features of digital products in production is the integration of Industry 4.0 technologies. This includes digital Twins, the Internet of Things (IoT), which connects machines and systems, and artificial intelligence (AI), which help to intelligently analyze and predict production processes. These Innovations are helping to improve production logistics by monitoring and analyzing production processes in real time (Hauge et al. 2020). These technologies enable more flexible and efficient production by providing real-time data and allowing adaptive control of processes. In logistics, digital products such as transport management systems, warehouse management systems and GPS-based tracking solutions facilitate the coordination and monitoring of supply chains (Barreto et al. 2014). They offer real-time transparency about the status of deliveries and enable more precise planning and route optimization. Another important aspect is the digital networking of the entire supply chain. The integration of various digital products creates a seamless flow of information between suppliers, producers, logistics service providers and customers (Ivanov et al. 2022).

3. Methodology

In order to identify the success factors, a literature analysis is carried out according to the method of Fettke (2006). Furthermore, the method of Webster and Watson (2002) is applied. With the phase model, Fettke (2006) provides a structured procedural model, which can be well supplemented in the "literature research" phase by the forward and backward search according to Webster and Watson (2002). The IEEE Xplore Digital Library, ScienceDirect, SpringerLink and Emerald Insight were used for the literature search. The electronic search for titles and abstracts was carried out using the following search terms: ("digital product" OR "product development") AND "feasibility analysis"; "digital product" AND "success factors" and "successful digital product" In addition, a search filter was selected from 2015 onwards. According to the search query, these searches resulted in a total of 640 publications. The abstracts of these publications were then checked for thematic relevance. After analyzing the abstracts and keywords, 16 relevant publications remained for the research focus. In addition to the database search, Webster and Watson recommend carrying out a forward and backward search. After this was carried out in a final step, the number of final publications could be increased to 21, which were read and coded in full. For the coding process of the factors, the qualitative content analysis procedure proposed by Mayring (2010) was carried out in the following points: In a first step, all publications were analyzed to identify success factors of digital products. Following the thematic synthesis process of Cruzes and Dybå (2011), corresponding text segments were identified from the 21 articles. These segments were

condensed into 15 topics that represent the success factors and are not mutually exclusive. Five categories were formed from the 15 identified success factors. In a final step, the success factors with the corresponding categories were used as columns and the relevant publications as rows for the concept matrix.

4. Findings

In the following section, the different inherent success factors of digital products identified from the literature analysis are briefly presented.

4.1. Product Uniqueness and Value

Product uniqueness and value are crucial for the market success of digital products. A clear value proposition, incorporating novelty and innovation, is essential for attracting investment (Berry 2017; Fernandes 2023; Yin et al. 2020).

Clear Value Proposition - A clear value proposition highlights the unique benefits and value a product promises to deliver to its users (Berry 2017; Böckle et al. 2023; Kristin et al. 2022; Lange and Drews 2020; Lange et al. 2021).

Innovative Product - An innovative product is characterized by its uniqueness and technological advancement, addressing unmet market needs (Giardino et al. 2014; Islam and Prasetyo 2020; Yin et al. 2020).

4.2. Market Alignment and Strategy

Aligning a product with market needs and developing strategies to capture market share are essential (Bosch et al. 2013).

Market Demand/Fit - Market demand/fit refers to how well a digital product meets the needs and desires of its target audience (Berry 2017; Böckle et al. 2023; Giardino et al. 2014).

Understanding Market/Customers/Competition - Understanding market size, growth potential, and competitive dynamics is crucial (Berry 2017; Fernandes 2023; Bosch et al. 2013).

Monetization Strategy - A monetization strategy encompasses potential revenue generation through various mechanisms such as subscriptions, in-app purchases, and advertising, directly impacting the product's sustainability and profitability (Berry 2017; Keller and Lima 2021).

Adaptability to Changing Market - Adaptability to changing market conditions is critical for sustained success, involving flexibility and agile development practices (Alshazly et al. 2021; Lange and Drews 2020).

4.3. Feasibility

Feasibility involves the practicality and viability of a product from both technical and business perspectives, including the assessment of resources, time, and technology needed for development (Alshazly et al. 2021).

Technical Feasibility - Technical feasibility assesses whether a product can be developed and maintained with current technology and practical constraints (Berry 2017; Alshazly et al. 2021).

Financial Feasibility - Financial feasibility focuses on cost-benefit analysis, funding strategies, and long-term financial planning to ensure economic sustainability (Berry 2017; Islam and Prasetyo 2020; Tanpure et al. 2023).

4.4. Architecture

Architecture involves the strategic design and implementation of technologies to support current operations and anticipate future needs, ensuring scalability, continuous operation, and integration across platforms (Alshazly et al. 2021; Kristin et al. 2022; Chen and Zhou 2018).

Scalability - Scalability refers to the ability to handle increased workloads or expansion without compromising performance (Alshazly et al. 2021; Lange and Drews 2020; Steffen et al. 2023).

Reliability/Robustness - Reliability and robustness indicate a product's consistent performance under various conditions (Cichosz et al. 2020).

Maintainability - Maintainability is crucial for the longevity and competitiveness of a digital product, involving ease of modifications and updates (Alshazly et al. 2021).

Data Security/Privacy - Data security and privacy involve protecting user information through robust encryption and compliance with data protection regulations (Böckle et al. 2023; Keller and Lima 2021).

Connectivity - Connectivity through APIs and middleware facilitates seamless integration with existing systems, enhancing user adoption and operational efficiency (Chen and Zhou 2018; Lange et al. 2021; Tanpure et al. 2023).

4.5. User Engagement

User engagement focuses on meeting user needs and incorporating their feedback to ensure satisfaction and continued use (Cichosz et al. 2020).

Ease of Use/UX - Ease of use and user experience directly affect user satisfaction and adoption rates, emphasizing intuitive design and user-centered principles (Alshazly et al. 2021; Böckle et al. 2023; Cichosz et al. 2020).

Customer Feedback Integration - Integrating customer feedback into the development cycle ensures the product's relevance and usability, adapting based on user preferences and market changes (Cichosz et al. 2020; Giardino et al. 2014; Tanpure et al. 2023).

5. Implications for the Area of Production and Logistics

The analysis of general success factors of digital products has shown that these are also highly relevant in the specific contexts of production and logistics. Although the literature analysis was cross-industry and not specifically focused on production and logistics, the success factors identified can be effectively transferred to these areas. In particular, the factors relating to the uniqueness and value of a product, market alignment and strategic planning as well as practical feasibility are universal - they are relevant for almost all types of digital products. A key finding is the realization that the scalability of digital products enables production and logistics processes to be flexibly adapted to changing requirements and production volumes. This is particularly important in an environment characterized by rapid market dynamics and

individual customer requirements (Koren et al. 2016). Another important success factor is the reliability and robustness of the digital solutions. In production and logistics, where downtime can lead to significant losses, ensuring high system availability and fault resistance is essential (Menon et al. 2018). Equally important is the maintainability of systems to enable rapid adaptation to new technologies or process changes while minimizing life cycle costs. Finally, connectivity plays a crucial role in the integration of different systems and technologies along the value chain. The ability to seamlessly exchange data between production sites, suppliers and customers enables more efficient planning and control of processes and contributes to the realization of concepts such as the Internet of Things (IoT) and Industry 4.0 (Queiroz and Wamba 2020).

6. Conclusion

This study could answer the research questions: Fifteen different success factors for digital products were identified and grouped into five critical categories that are of great importance to the manufacturing and logistics industries. These categories are crucial for the successful implementation and management of digital technologies in these sectors. Their application is critical to driving innovation and maintaining competitive advantage in an increasingly digital market landscape. For companies in manufacturing and logistics, these factors serve as a roadmap for developing, optimizing and evaluating digital products that meet the complex demands of modern industry.

6.1. Critical reflection

The literature analysis identified a number of inherent success factors of digital products which can be used to determine the potential success, but there may be other factors that were not identified in this literature analysis. Furthermore, due to the large scope of this topic, only a limited number of databases and search terms were searched, so there is a possibility that additional factors could be identified.

6.2. Outlook

Future research could focus on developing a methodology that uses the success factors identified in this study as parameters in an evaluation system. The aim would be to generate a quantitative value that represents the potential success of digital products in production and logistics. This methodology would make it possible to provide a well-founded assessment of the prospects of success of new digital solutions before their market launch and could therefore serve as a valuable tool for decision-makers and developers.

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Towards Assessing the Potential Success of Digital Product Ideas in the Area of Production and Logistics

Y. Langer, J. Mall & C. Sandbrink
Heilbronn University, Heilbronn, Germany

Abstract: This work presents an evaluation methodology for digital product ideas in the field of production and logistics, based on a careful analysis of success factors and expert interviews. The aim is to enable a systematic evaluation and prioritization of product ideas. By applying the methodology to various product ideas, it was possible to demonstrate its ability to perform a differentiated evaluation and identify projects with different potential for success. The study proves the predictive power of the developed evaluation matrix and offers practical insights for early decision-making in digital product development. The methodology promises to provide decision-makers with a valuable tool to effectively evaluate the chances of realizing product ideas.

Keywords: Digital product ideas, Evaluation methodology, Expert interviews, Production and logistics, Decision-making.

1. Introduction

In the dynamic landscape of manufacturing, digitalization has created a multitude of new opportunities. The opportunity for digital transformation has meant that companies are faced with a significant range of potential digital products that result from numerous use cases (PWC 2016). While these transformation opportunities and the diversity of potential products are encouraging, they have also created a challenging situation for the companies. A possible challenge is the market pressure, manifested through competition and the need to control costs (Mourtzis 2022).

The challenge for companies is to identify those opportunities that are not only profitable but also provide a clear competitive advantage. This challenge is further complicated by rapidly changing market conditions (Butryn 2020). Deciding which digital product idea to implement therefore requires not only creativity, but also a precise strategy that balances profitability with the ability to innovate. This raises the question of how companies in the manufacturing industry can manage the diversity of potential digital products, identify the most promising ideas and efficiently transform them into competitive products while managing cost pressures and market requirements.

The diversity of potential products significantly increases the complexity of portfolio management (Brzęczek 2020). Therefore, a balanced strategy is required that takes into account both innovation and profitability while maintaining competitiveness in a highly dynamic industry.

To meet the challenges of digital product portfolio management in the manufacturing industry, this work emphasizes the creation of a refined approach. It involves a deep understanding of market requirements and the identification of high-potential digital product concepts, and the integration of these elements into a streamlined, strategic decision-making framework. To solve the presented problem, the following research question and sub-questions are created:

"How can a methodology be developed to effectively assess and prioritize potential digital products for production and logistics?"

Q1: What factors are relevant towards an assessment of potential digital products?

The main objective of this paper is to develop a practical methodology for prioritizing and evaluating different use cases and business cases. Based on different techno-economical portfolio parameters which have been found in the literature (Langer 2024), a techno-economical portfolio value is being calculated. The parameters are key factors which help to determine which digital products have the best chance of success in the marketplace. The techno-economical portfolio value is intended to represent the potential of various digital product ideas. The methodology is designed to effectively support companies in the manufacturing industry in identifying, evaluating and strategically prioritizing the most promising ideas in order to create a basis for decision-making in product development.

2. Theoretical Background: Industry 4.0

Industry 4.0 represents the fourth industrial revolution, characterized by the profound integration of digital technologies into the manufacturing industry. This concept is based on the networking of factories, machines, systems and processes using advanced information technologies to enable intelligent and flexible production (Frank et al. 2019). At the core of Industry 4.0 are the Internet of Things (IoT), cyber-physical systems (CPS) and artificial intelligence (AI), which work together to create autonomous, self-organizing production systems that are able to adapt independently to changes and continuously optimize (Sanchez et al. 2020).

The introduction of Industry 4.0 enables efficiency and flexibility in production. By using IoT, companies can collect real-time data on the condition of their machines and systems, which promotes preventive maintenance and optimized resource utilization (Soori et al. 2023). Cyber-physical systems allow a deep integration of physical production processes with digital planning and control systems, resulting in a high degree of automation and adaptability (Dafflon et al. 2021). Another key element of Industry 4.0 is the use of AI and machine learning, which enable the analysis of large amounts of data in order to recognize patterns, make predictions and support decision-making processes (Jagatheesaperumal et al. 2022).

Despite challenges including the need to invest in appropriate IT infrastructures, train employees and manage data protection and security risks (Ghobakhloo 2018), Industry 4.0 offers significant opportunities for companies to improve their production efficiency, bring innovative products to market faster and meet more individual customer requirements.

3. Methodology

For the scientific design of the research process of this paper we follow the established procedure according to (Peffers et al. 2007). In the first step of the design and development phase, 22 expert interviews were conducted based on Mayring's (2015) structured procedure for performing expert interviews. The selected experts brought specific knowledge either from the process of digital product evaluation or from the areas of production and logistics, coupled with extensive experience with digital products. The aim of the interviews was to evaluate the success factors previously identified from the literature (Langer 2024), assess their criticality

and identify possible new factors. The findings from the interviews were documented in a matrix that included both the assessed and newly identified factors. This matrix not only facilitated the visualization of the data, but also supported the development of a metric that was used to determine the importance of each factor and ensure that only the essential factors were included in the methodology. In the second step, definitions were developed for the relevant newly identified factors based on the expert interviews. This was done to create a common understanding for subsequent applications and assessments. Also, the selected factors were operationalized. A scoring range was defined for each factor to enable measurable and comparable assessments. This gave each factor a clear definition, a specific weight and a scoring system. In the last step of this phase, the methodology was developed to normalize and calculate an overall score on a scale of 0-100. This scaling enabled a standardized evaluation of the success factors. In the final step, the developed methodology was evaluated. With the help of an evaluation matrix, which included the new methodology, various digital product ideas that had previously been evaluated using other methods were re-evaluated together with experts in order to check the effectiveness and reliability of the methodology.

4. Presentation of the Artifacts

4.1. Evaluation Matrix – Expert Interviews

The systematic evaluation and analysis of the success factors of digital product ideas in the area of production and logistics requires comprehensive data collection and evaluation. In order to create a solid empirical basis for the study, 22 expert interviews were conducted. The resulting quantitative and qualitative data was carefully recorded in a matrix, which forms the core of the analytical work. This matrix serves as a central instrument for recording the experts' assessments of each individual factor and enables a precise evaluation of the information collected.

As part of the expert interviews, an evaluation and assessment of all factors identified from the literature was carried out. Each factor was assigned a value on a scale of one to five, reflecting its specific weight. In addition, the expert interviews led to the identification of further factors that were not mentioned in the previous literature. These new factors were also assigned a corresponding weighting.

4.2. Conceptualized Methodology

Careful selection of the factors is essential for the design of the methodology. By consulting the experts, a border value was determined, so that only those factors with an average value of 3.5 or higher are considered. This approach ensures that only factors of significant relevance and influence are included in the final methodology. The definitions of the selected, relevant factors, as set out in Langer (2024), serve as a basis and are summarized concisely below. This consistent focus allows the essence of the methodology to be refined and ensures that the selected factors provide a robust and meaningful basis for evaluating and analyzing digital products in the field of production and logistics.

Clear Value Proposition: A clear value proposition articulates the unique benefits and value that a digital product or service promises to its users. It is critical to differentiate from competitors and explain why this differentiation is valuable, especially to attract investment.

Market Demand/Fit: Market demand/fit refers to the extent to which a digital product meets the needs and wants of its target market. It is essential to match products with the needs of potential customers who are willing to invest in them.

Understanding Market/Customers/Competition: Understanding the market, customers and competition is crucial to ensure the success of a product. The stakeholders need to have a deep understanding of these subjects.

Adaptability to changing market: The adaptability of a digital product to changing market conditions is a critical factor for its continued success. Flexible business modeling and agile development practices are necessary for this.

Technical Feasibility: Technical feasibility is a determinant of whether a digital product can be developed and maintained with current technology and within practical constraints. It includes the assessment of technical resources and expertise.

Financial Feasibility: Financial feasibility is critical to assessing the viability of digital products, focusing on cost-benefit analysis, funding strategies and long-term financial planning.

Scalability: Scalability refers to the ability of a digital product to handle growing workloads or be expanded to support this growth. This includes the technical ability to expand and the capacity of the business model.

Reliability/Robustness: Reliability and robustness of digital products means that a product can consistently perform its intended functions under different conditions. This is crucial for user trust.

Data Security/Privacy: Data security and privacy enhance user trust by protecting their personal information from unauthorized access and breaches. The implementation of robust encryption methods and compliance with global data protection regulations are essential.

Connectivity: Connectivity, especially in terms of integration with existing systems, is a critical factor in the success of digital products. It enhances the value of new software by ensuring seamless interaction with established ecosystems.

Careful selection of the new factors identified through expert interviews is also crucial for the development of the methodology. Only those new factors that were mentioned at least four times (corresponding to around 20% of respondents) were taken into account. This selection strategy ensures that only factors with a significant frequency of mention and thus a higher perceived relevance are included in the methodology.

It is necessary to derive definitions for these new factors directly from the content of the expert interviews. This approach enables a deeper understanding and ensures that the definitions authentically reflect the experts' opinions and insights. The new factors identified from the interviews were introduced separately to emphasize their specific relevance and impact, avoiding the dilution of existing categories and ensuring a precise and effective analysis.

Acceptance of End Users - End user acceptance refers to how well a target group adopts and uses a new software or technology. Success hinges on involving end users in the development process, clearly communicating benefits, and minimizing frustrations from malfunctions or complexity. In B2B contexts, aligning with both buyers and actual users is crucial to ensure high acceptance.

Generalizability - Generalizability is the ability of a solution to apply effectively beyond its initial context, maintaining effectiveness across various situations. This trait depends on a solution's scalability and portability, which facilitate its extension to new areas without significant adjustments.

Solution to a Specific Pain/Business Problem - This factor assesses how well a solution addresses a distinct problem or need within a business, highlighting its relevance by alleviating a specific "pain" or enhancing a process. Effective problem identification and solution tailoring are vital for market success.

Team Organization - Team organization involves structuring a project team to support development and implementation efficiently. It includes clear role definitions, effective communication, and alignment on shared goals, with team cohesion and stakeholder engagement being critical for project success.

Adaptability to Specific Requirements; Customizability/Modularity - This factor describes a solution's flexibility in adapting to various user needs through customizability and modularity, allowing users to tailor functions or modules as needed. "T-shirt sizing" is one method used to balance customization with scalability, offering different feature packages suited to different organizational sizes.

Business Value and Profitability - This factor combines economic benefits and quantifiable value delivered by a solution, focusing on ROI and other measurable impacts like cost savings, profit increases, or improved investment returns. Demonstrating concrete, quantifiable value is essential for both internal assessments and customer negotiations, enhancing the solution's market success potential.

Now that all relevant factors have been defined and assigned appropriate weightings, the study enters a crucial phase: the development of the scoring system. This step of operationalization aims to establish an appropriate scale or range for each factor that is precisely defined. Carefully designed scaling is crucial as it forms the basis for an objective and differentiated evaluation of the product ideas.

Operationalization in general refers to the process of translating abstract concepts into measurable indicators, allowing for a precise and practical application of theoretical concepts. In the context of this methodology, this means that specific criteria and measurement scales are developed for the success factors in order to transform them from theoretical constructs into quantifiable and assessable units. This process forms an essential bridge between the theoretical definition of success factors and their application in the evaluation of product ideas by creating an objective, clear and repeatable evaluation methodology. The scoring process involves not only defining the rating scales, but also clearly defining what each level of the scale represents. This ensures that the scores are consistent and comparable, regardless of the person doing the scoring. By precisely defining each scale level and carefully selecting the wording, a framework is created that enables the evaluation of new product concepts.

An example would be: Clear Value Proposition:

0: N/A or not necessary

1: The value proposition is either not recognizable or so vague that a concrete benefit for the customer can hardly be identified.

2: A value proposition exists, but is weakly formulated or unclear, making it difficult for the customer to understand the benefit.

3: The value proposition is recognizable and reasonably clearly formulated. Customers can understand the benefit, even if it does not stand out in every respect.

4: The value proposition is strong and clearly communicated so that customers can immediately recognize the benefits.

5: The value proposition is communicated exceptionally clearly and convincingly.

4.3. Calculation of the Final Score

With the factors defined and weighted, the next step is to calculate the final Techno-Economic Portfolio Value, a crucial value that reflects the technical and economic viability of product ideas. This process involves several carefully executed steps to ensure a precise and meaningful valuation.

First, a normalization is performed for each factor to create a comparable basis between the different evaluation scales. This normalization is calculated by multiplying the selected value of a factor by its weight in relation to the range of possible values, also weighted. This makes it possible to assign a value between 0 and 1 to each factor, creating a basis for a fair and consistent aggregation of the values. After the normalization, the normalized values of all factors are added together. This represents the total number of factors. This sum forms the basis for calculating the total score and takes into account the individual weight of each factor. This aggregation ensures that each factor is included in the overall assessment according to its importance. In the final step, the relative score is calculated on a scale from 0 to 100. This conversion is carried out by dividing the calculated total by the number of factors N and multiplying by 100. This final calculation provides a percentage value that represents the Techno-Economic Portfolio Value.

This step creates a clearly understandable and comparable value that enables a comprehensive assessment of the technical and economic attractiveness of a product idea.

4.4. Evaluation of the Methodology

The developed evaluation methodology was tested using various product ideas from production and logistics to verify its validity and applicability. The product ideas were categorized into three groups: dropout cases, cases in validation, and cases with a positive investment decision. Each use case was evaluated using a scoring matrix that assesses factors such as market fit, technical feasibility, and scalability.

The evaluation results show a broad spectrum of potential and risks among the considered product ideas, with scores ranging from 51.9 to 85.8. Lower scores corresponded to dropout cases, indicating the methodology’s ability to identify less viable projects early. Higher scores were linked to cases with positive investment decisions, highlighting the methodology's effectiveness in predicting the potential success of digital product ideas. This confirms the evaluation methodology as a robust tool for initial assessments and offers insights into different stages of product development.

5. Conclusion

This study presents an evaluation methodology based on expert interviews and the careful evaluation of success factors. The application of the methodology to a diverse selection of product ideas in the field of production and logistics has confirmed its ability to differentiate between different prospects of success. The correlation between the calculated scores and the real development paths of the use cases illustrates the predictive power and practical value of the methodology. This result underlines the potential of the methodology to serve as an effective tool for early evaluation and decision-making in digital product development.

5.1. Critical Reflection

The chosen research methodology proved to be appropriate and effective for the development of the evaluation methodology for digital product ideas. It enabled a well-founded identification and weighting of relevant success factors. However, this research methodology also has its limitations. One challenge lies in the subjective nature of expert interviews. Despite careful selection of the experts and the use of structured interview techniques, individual assessments and experiences can lead to distortions. In addition, the transferability of the results to other sectors or use cases is not readily given, as the success factors identified were developed specifically for the production and logistics sector. In addition, non-measurable "soft factors" such as coincidence, timing and political influences were not taken into account, although these can be decisive for success in the start-up environment. Despite these limitations, the methodology provides a robust basis for the evaluation.

5.2. Outlook

The insights gained in this paper provide a starting point for future research. Future studies could focus on expanding the database by integrating additional expert opinions from different industries to increase the universality and adaptability of the methodology. Additionally, future projects could explore the development of AI-powered algorithms capable of automating and refining the evaluation processes by recognizing complex data patterns and offering predictive analytics to forecast market success. Extending the methodology with AI-based techniques could not only improve the efficiency and accuracy of assessments, but also provide deeper insights into the dynamics of production and logistics.

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The Future of Business Process Simulation in Scientific Research and Academic Education

H. Sperling, H. Scheruhn, L. Kirchdorfer, P. Sieboth, R. Bluemel
SAP SE, Walldorf, Germany
Harz University of Applied Sciences, Wernigerode, Germany

Abstract: Business process simulation allows decision makers to predict the impact of changes in process execution on overall business process performance. Despite its potential to convey in-demand analytical skills, business process education has largely focused on traditional process modelling and process mining techniques. Using a sales distribution process example developed at Harz University of Applied Sciences, we demonstrate how process simulation can be employed as an effective tool for teaching process optimization. In the first part of the paper, we illustrate how relatively simple, parameter-based business process simulation models built in SAP Signavio Process Transformation Suite, academic edition, can serve as a viable alternative to process mining in data-driven business process management (BPM) education. In the second part of the paper, we provide an overview of current research on process simulation to underscore its future potential. Data-driven and agent-based approaches to business process simulation may facilitate the teaching of artificial intelligence (AI) and advanced analytical skills to students, thereby significantly enhancing current BPM education.

Keywords: Agent-based simulation, AI, BPM, process mining.

1. Introduction

Business process simulation denotes the practice of modelling artificial abstractions of business operations to generate business process instances with process resources, activities, and other parameters. As a valuable tool for organizations to make data-driven decisions (McKinsey 2020), the technique has become widely used in research and practice to analyse the quantitative properties of business processes (Estrada-Torres et al. 2021). On the one hand, process simulation can be based on manual assignment of simulation parameters to simulate different business scenarios. In educational contexts, this has been shown to increase students' understanding of BPM and the BPM lifecycle, as well as help with the analysis of business process performance (Saraswat et al. 2014, Chow 2021). On the other hand, data-driven simulation allows for automatic discovery and calibration of business processes from process data, traditionally in the form of event logs (Camargo et al. 2020). With the rise of multi-agent systems and other artificial intelligence (AI) concepts, new and more sophisticated approaches to process simulation research emerge. This study provides an overview of process simulation in academic education as well as current developments in simulation research to emphasize the topic's relevance for future academic inquiry.

The first part of this article consists of an exploratory case study introducing business process simulation in the educational context of Harz University of Applied Sciences (in the following: Harz University). The case illustrates how process simulation can be leveraged in academic teaching and highlights its value in conveying analytical problem-solving skills. The subsequent part introduces automated simulation approaches and focuses on recent developments in process simulation research to highlight potential future extensions of current

educational simulation approaches. After reviewing process simulation in academia, we conclude with a call for more simulation curriculum development and scientific research on the topic.

2. Process Simulation in Academic Education

2.1. Educational Setting

Analytical and creative thinking remain top in-demand skills for the future job market (World Economic Forum 2023). Simulating different business scenarios and predicting their outcomes under differing conditions allows students to practice data-driven decision-making and learn how to improve efficiency, effectiveness, and overall performance of business processes. Recognizing the benefits of advanced BPM, Harz University has started integrating process simulation into current enterprise resource planning (ERP) education. Students learn to navigate different processes from a business as well as system-based perspective using the Enterprise Online Guide (EOG, Scheruhn et al. 2023). As a conceptual representation of an ERP system, the EOG is based on business processes as a structural organizational feature of a company and focuses on the transformation of these processes (Scheruhn et al. 2023).

As part of the EOG, Harz University used BPMN 2.0 (Object Management Group 2024) to model the sales and distribution (SD) process from existing ERP curricula in the academic edition of SAP Signavio (SAP Signavio 2024b). The SAP Signavio Process Transformation Suite is an integrated platform for business process management and related capabilities (SAP Signavio 2024a). Its academic edition is free of charge for academic faculty and students and offers advanced process modelling capabilities alongside a module for business process simulation.

The standard educational case study "Sales and Distribution" (in the following: standard SD case study) by Harz University and the SAP UCC Magdeburg has been in academic use for more than 10 years. The case study's associated lead-to-cash (L2C) process spans three departments and eight workplaces across two company subsidiaries in the US and Germany (Appendix A1). Using EOG, we conducted an analysis of the standard SD case study to identify potential areas of improvement. We then designed a modified version of the standard SD case study to integrate our findings and include process mining as well as simulation to foster problem-based thinking. The resulting case study SD8 lets students detect where time-consuming transitions or media breaks occur between workplaces, and identify which documents are exchanged upon customer contact (Scheruhn & Mendling 2024). Access to the full online version (including customer journey map) on academic.signavio.com can be granted upon request to the authors from Harz University.

2.2. Evaluation of the Sales & Distribution Simulation

While process mining activities analyze process efficiency, process simulation in case study SD8 was used to address questions of process effectiveness. For example, process effectiveness for customer-related activities is addressed as quotation- or order probability (depicted in Fig. 1 by multiple potential starting points and end events). An extended to-be process may start with the events (80) *Initiative quotation to be created* and (80) *Customer orders received without reference*. Students may assign different quotation/order probabilities in the numerous decision gateways of the process. Gateway execution decisions can be adjusted in percentages

(*e.g., 75% quotation accepted, 5% quotation rejected, 20% modified quotation to be created*), leading to different simulation scenarios (see Fig.1).

Table 1: Simulation settings 1 for role "Customer agent"

Work schedules: ***Mon – Fri 9am – 5pm***	**Cost/ hour**	**Execution time:** ***Create quotation***	**Execution time:** ***Create sales order***	**Waiting time: Mod. quotation to be created**	**Waiting time: Customer order (wholesale)**
40 hours/week	60€	10 min	10 min	10 min	10min

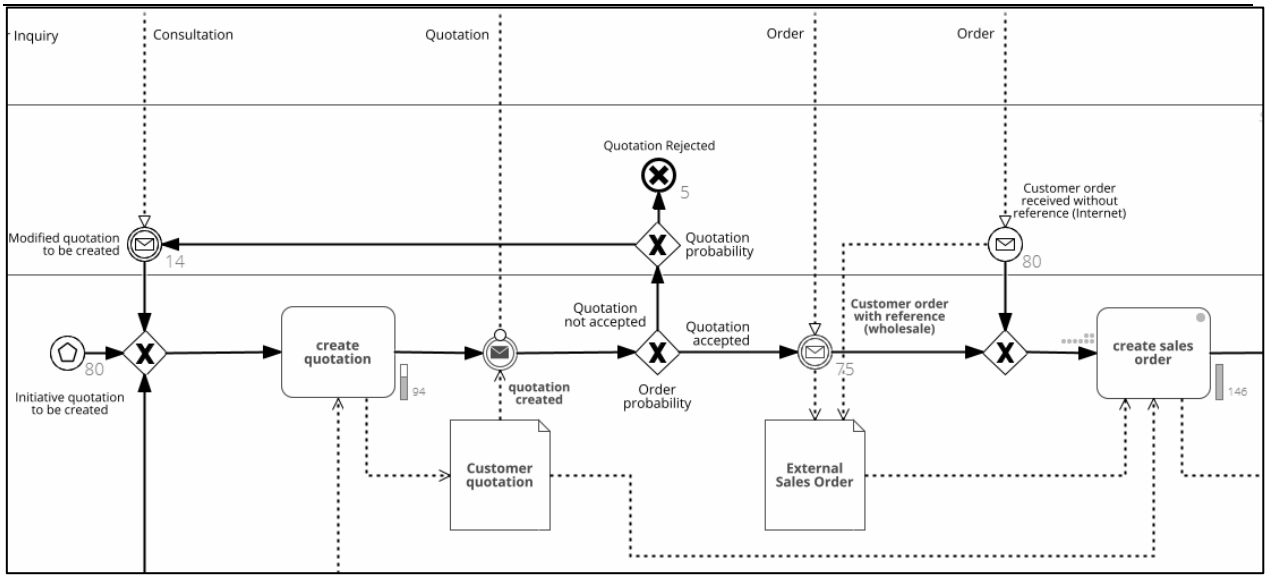

Fig. 1: Excerpt of Harz University's BPMN diagram of the SD8 process. Bottlenecks in process execution in the simulation module of SAP Signavio Process Transformation suite are visualized by process tokens as small bubbles, piling up at the respective activity (here: *create sales order*).

Moreover, the simulation module of SAP Signavio allows for manual adjustment of execution times. Starting with the default simulation settings (regular working weeks, default capacity) and a certain number of instances (Tab. 1) of the SD8 process, a bottleneck occurs.

After analysing the potential causes of the resulting bottlenecks, students went into an ideation phase on how to resolve them. As an example, multiple employees in the impacted roles (swim lanes) could be used to handle the process volume more effectively, e.g. by pooling resources/working hours or employing additional people or using efficient ERP systems like SAP S/4HANA. An interesting improvement results from reducing the number of *Initiative quotations to be created* (see Fig. 2)

Table 2: Simulation settings 2

Gateway	**Decision: Order probability**		**Decision: Quotation probability**	
Decision	Quotation accepted	Quotation not accepted	Modified quotation to be created	Quotation rejected
Probability	75%	25%	80%	20%
Start event	Initiative quotation to be created (Mon)		Customer order received without reference (Internet) (Mon – Fri)	
Frequency	80		80	

Frequency opt.	75	80

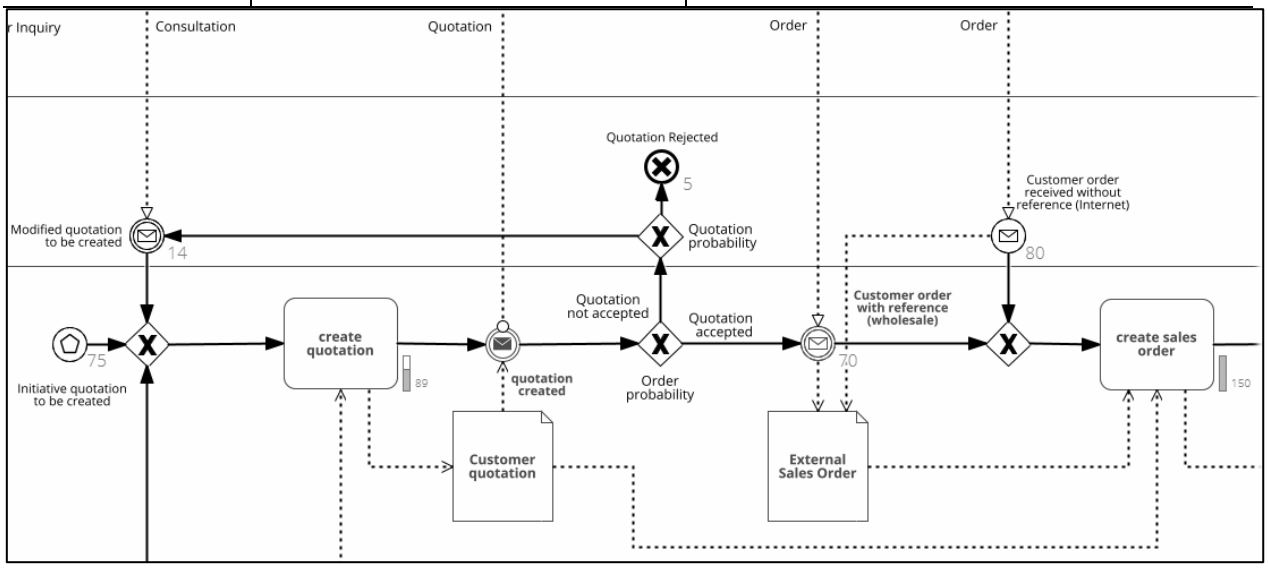

Fig. 2: After reducing the number of *Initiative quotations to be created* from 80 to 75, the bottleneck disappears. Using the saved processing time for *create quotation* increases the number of *create sales order* activities from 146 to 150.

2.3. Future Extensions

BPM education has so far largely focused on process mining using event-logs (see Tab. 2) as a technique to convey data-driven reasoning skills. Harz University's case study on process simulation illustrates how business process simulation does not have to be taught as an alternative to process mining education. Instead, both techniques complement each other, fostering analytical problem-solving skills and creativity in advanced BPM education. For example, a conformance check based on process mining can provide valuable insights for the design of a to-be process using process simulation (Fig. 4). In this combination, process mining and process simulation used in education can convey both process efficiency and process effectiveness considerations in BPM. Extending manual parameter selection in simulation education by event-log based simulation techniques (potentially in combination with agent-based approaches) provides further potential for future academic education.

Table 2: Sample event-log excerpt for process conformance check.

CaseID	Activity	Timestamp	Role	Time
2	Create quotation	2021-11-28T13:57:19	Customer agent	
2	Create sales order	2021-11-28T14:39:05	Customer agent	41:46
11	Create quotation	2021-11-28T15:18:52	Customer agent	
11	Create sales order	2021-11-28T15:30:29	Customer agent	11:37

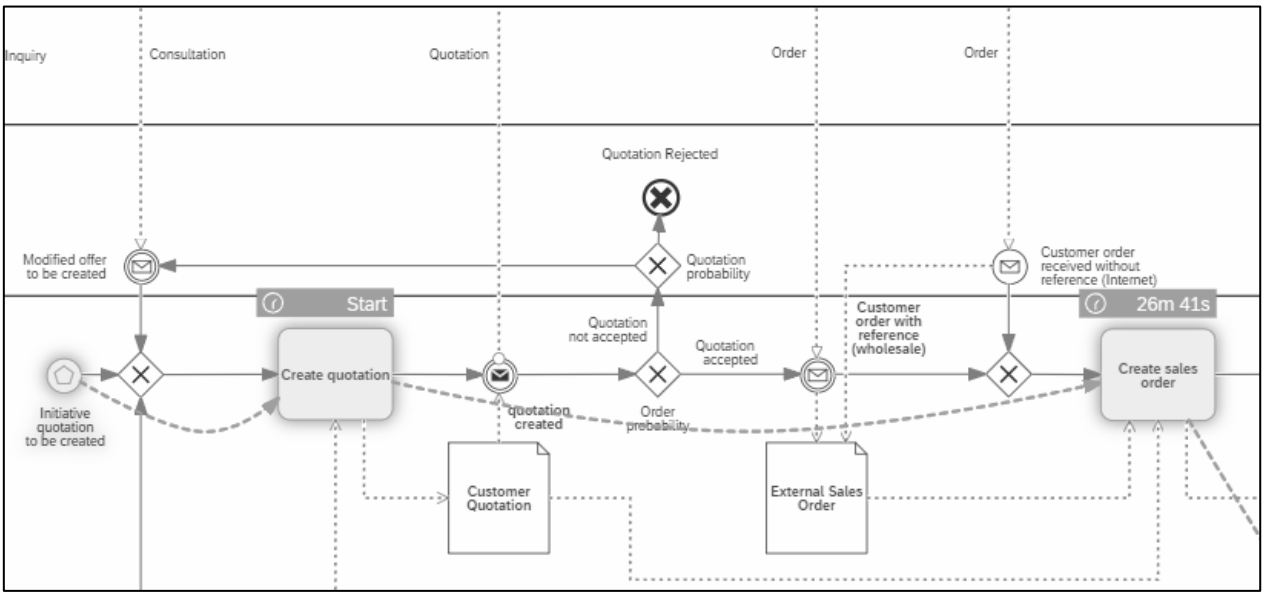

Fig. 3: Based on an event-log, a process conformance check focusing on process efficiency can be carried out for the existing as-is process flow with SAP Signavio (customer edition). In our example, process mining serves as a foundation for simulating to-be process effectiveness, modeled from the customer perspective.

Overall, the exploratory case study on SD8 process simulation at Harz University emphasizes the value of advanced BPM methods to teach data-driven problem-solving skills in academic education. Students involved in building the simulation model built several simulation scenarios to trouble-shoot process execution and resolve bottlenecks. Experimenting with various simulation parameter settings as well as decision gateway probabilities, they were able to creatively engage with the formal structure of their SD8 process BPMN model. Although this manual process of setting simulation parameters yields important learnings, more advanced process simulation approaches also hold potential for academic education. Therefore, the last paragraph of this paper reviews data-driven simulation approaches in research as possible future extensions in education.

3. Process Simulation Research

3.1. Data-driven Approaches

Extending the simplistic, manual assignment of parameters in process simulation as described above, research on automated business process simulation approaches can generally be divided into three categories, more specifically into Data-Driven Process Simulation (DDPS) approaches, Deep Learning (DL) simulation, and hybrid approaches. DDPS approaches such as Simod (Camargo et al. 2020) automate simulation model discovery from event logs by initially identifying a process model and then enhancing it with simulation parameters like activity durations or inter-arrival times. More recent studies try to improve some of the overly simplistic assumptions of DDPS approaches, e.g., by considering distinct resource availability and performance (López-Pintado & Dumas 2022). DL approaches for business process simulation typically rely on recurrent neural networks, such as the DeepGenerator approach (Camargo et al. 2019), which incorporate n-grams and embeddings to iteratively predict the next activity, resource, and timestamp. However, due to their black-box nature, DL models are not applicable for what-if analysis, which involves changing simulation parameters and assessing those changes in the simulated output. Thus, hybrid models such as the

DeepSimulator (Camargo et al. 2022) seek to overcome this limitation by combining DL and DDPS elements, using both a stochastic process model and a DL model for simulating the underlying process to retain what-if analysis capabilities.

3.2. Agent-based Process Simulation

Business processes are artificial abstractions that model how business operations are conducted within an organization toward the accomplishment of a specific business goal (Dumas et al. 2018). While they are crucial for managing work in socio-technically complex contexts, work itself is typically not carried out in a naturally process-oriented manner. Instead, each resource agent carries out work from their own perspective. This means that for simulation purposes, a purely process-oriented approach may not be the most realistic one, as it provides a simplistic view on how resources ("agents") act within an organization. For example, a customer agent or sales representative as described in the simulation setting above may allocate certain parts of their day to deep-dives that allow them to solve complex issues and handle trivial issues at times of the day during which frequent interruptions can be expected. To model such behaviour, agents can be used to represent each of these resources. The notion of such an agent ultimately represents a fundamental abstraction in AI (Russell & Norvig 2020). Over the past decades, the application of multi-agent systems across various domains has been extensively studied (cf. Dorri et al. 2018). The idea of applying multi-agent systems to BPM emerged in the 1990s (Jennings et al. 1996), modeling business processes as negotiating agents. Recently, the concept of agent system mining has been introduced, acknowledging that processes often result from interactions among autonomous agents (Tour et al. 2021), as demonstrated by an agent-based discovery algorithm (Tour et al. 2023) and shown for simulation (Halaska & Sperka 2018). For a general introduction to agent-based business process simulation, see (Sulis & Taveter 2022).

However, to the best of our knowledge, previous agent-based simulation approaches in BPM rely on manual configuration, such as in factory production (Dornhöfer et al. 2020). Thus, the novelty lies in automatically instantiating and discovering a multi-agent system for simulation from an event log. In these cases, it is necessary to define agent behaviour beyond simple resource availability schedules: agent policies (either learned or manually specified) can define the context-sensitive criteria that agents apply autonomously for task selection. Simulation approaches that implement such relatively nuanced resource behaviour can be considered agent-based An example simulation flow that makes use of this agent paradigm is depicted in Fig. 4. Different agents of varying roles (types) are discovered together with information on their capabilities (sets of activities they can perform) and availabilities (their working calendars). The simulation flow is then determined by these parameters such that in the example below Agent 1 must ask Agent 3 to take the process case and execute the next activity, because Agent 2 is not available, and Agent 4 is of a different type and cannot work on the following task. These agent internals (i.e., their reasoning loops), which determine when and how to act, can be implemented using abstractions of different levels of sophistication: simple logic-based rules allow for straightforward interpretability. More sophisticated approaches, such as reinforcement learning loops, or LLM-based agents, may be able to support self-correcting and primitively 'social' behaviour.

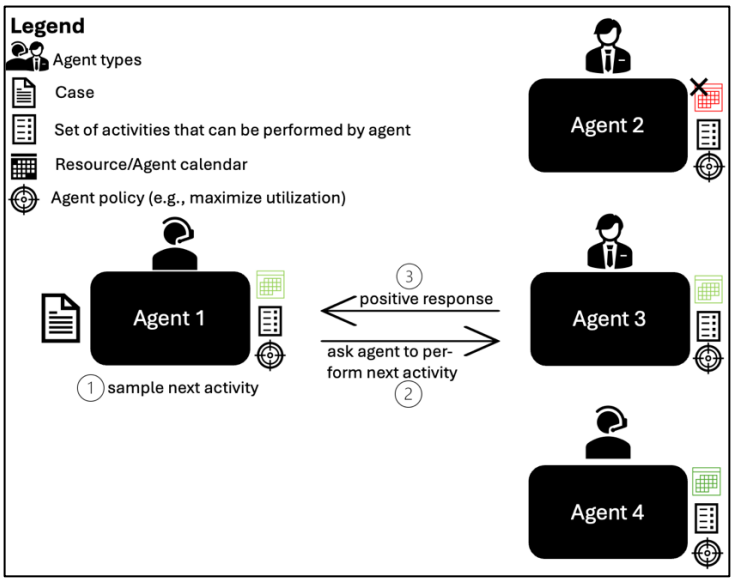

Fig. 4: Agent-based data-driven process simulation: preliminary pseudo-simulation process (simplified).

3.3. Value Assessment

Agent-based simulation can be an alternative to other data-driven process simulation approaches. First prototypical experiments indicate that agent-based approaches can beat state-of-the-art simulators on key metrics while running substantially faster and requiring merely a fraction of the computing cost. Hence, we assume that agent-based simulation can be a viable alternative to traditional data-driven (event log-based) simulation, also because agent-based simulation can be fused with variants of the agent system mining approaches described above to allow for an integration of model-based and data-driven process intelligence in the context of simulation. Another potential advantage is that focusing on the agent view can allow for a *divide & conquer* approach to simulation, focusing *what-if* analysis on subsystems that are well understood. One additional important advantage compared to traditional data-driven simulation is higher flexibility due to the independence of an imperative process model. Agent-based simulation does not require discovering an imperative, Petri net-style process model, as it relies on agent objectives and declarative rules (and potentially other functions for local decision-making) instead.

While agent-based simulation appears to have some advantages over classical approaches to data-driven (event log-based) process simulation, more research is necessary to produce more evidence that i) quantifies this advantage and ii) examines the root cause of the advantage.

4. Discussion and Outlook

With increasing importance of data-driven decision making and the rise of AI, process simulation techniques play an important role in both academic education and scientific research. While simulation of business processes in BPM teaching to date remains rather simplistic, the value proposition for data-driven decision making and process optimization is already clear. Advances in process simulation research highlight the growing potential of the topic for future educational use. Moving forward, further research on conceptual approaches to agent-based simulation are needed to shed light on the assumption that agent-based simulation indeed outperforms other data-driven process simulation approaches. Educators may look to

simulation research for inspiration on how to advance current BPM curricula and increasingly focus on process simulation as a viable alternative to process mining curricula in advancing students' problem-solving skills.

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6. Appendix

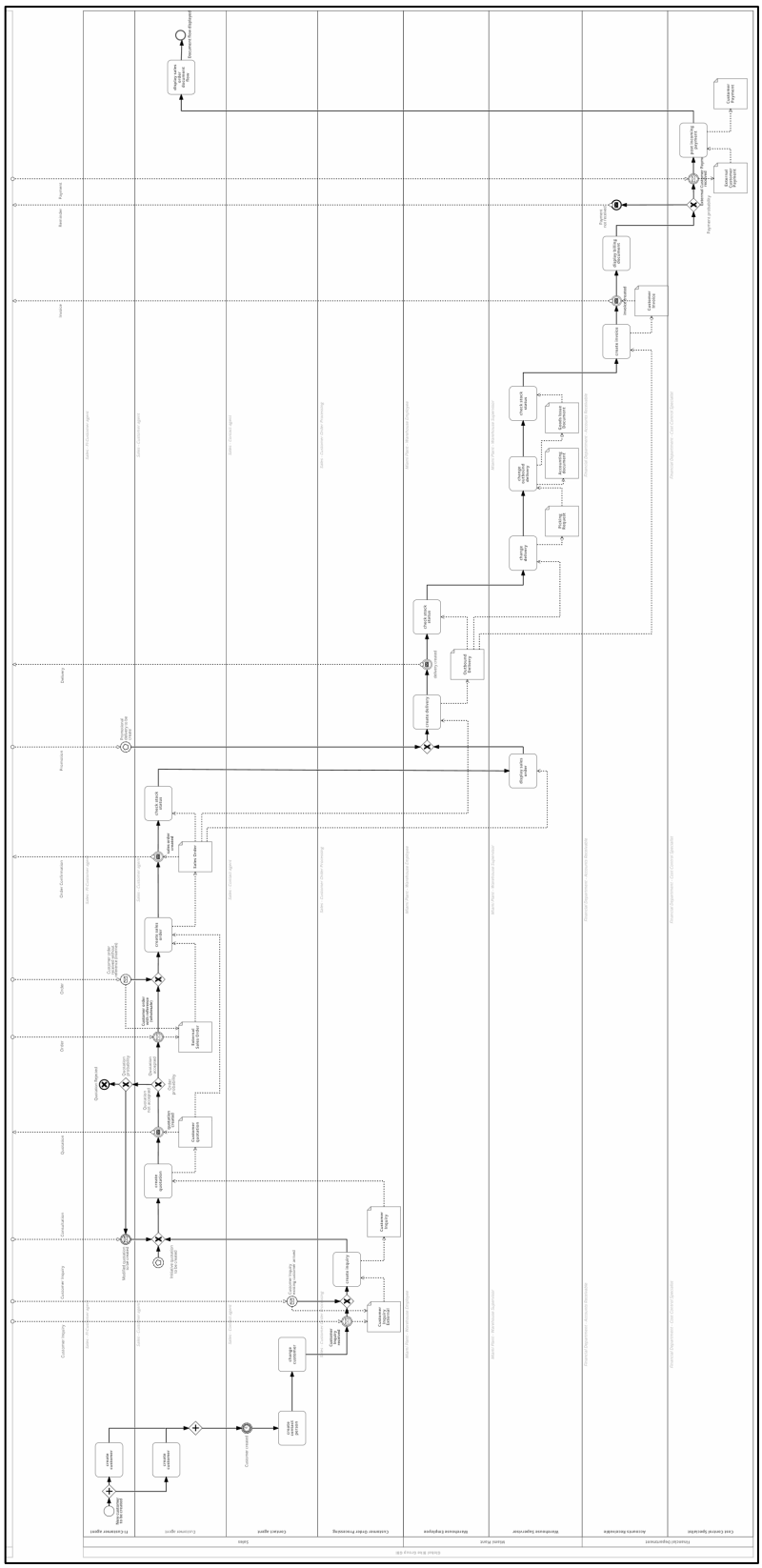

Fig. A1: Simplified version of the sales and distribution process BPMN model for illustrative purposes (external stakeholders removed to reduce complexity).

SAP Business AI in Unternehmen und an Hochschulen

Dr. Matthias Sessler, Felix Sasaki
SAP SE, Deutschland

Abstract: In den letzten Jahren hat sich der Bereich der künstlichen Intelligenz und der generativen künstlichen Intelligenz sehr schnell entwickelt. Es ist viel einfacher geworden, künstliche Intelligenz gewinnbringend einzusetzen als noch vor Jahren, weshalb die Zahl der Nutzer deutlich gestiegen ist. Während es inzwischen viele sehr gute technische Services gibt, die bereits sehr weit verbreitet sind, wie zum Beispiel Gesichtserkennung, semantische Dokumentenerkennung, Generierung von Texten und Bildern, geht es nun darum, die neuen Möglichkeiten in die Unternehmenssoftware einzubringen. SAP nimmt hier eine Vorreiterrolle ein, und wir möchten die aktuellen und zukünftigen Möglichkeiten sowie die rechtlichen und ethischen Grenzen beleuchten. Des Weiteren werden auch die Auswirkungen der künstlichen Intelligenz auf die akademische Lehre diskutiert.

Identifikation, Entwicklung und Qualifizierung von Business Cases für Generative AI: Ein integrativer Ansatz aus Design Thinking und Enterprise Architecture

Dr. Markus Lauff
SAP SE, Deutschland

Abstract: In einer zunehmend digitalen Welt ist es entscheidend, neue Technologien wie Generative AI gezielt und effizient einzusetzen, um Wettbewerbsvorteile zu erzielen. Experten, Entwickler und Entscheider, sind daher daran interessiert, das Potenzial von Generative AI für innovative Geschäftsstrategien und -lösungen zu nutzen.

In diesem Vortrag wird ein integrativer Ansatz vorgestellt, der Methoden aus dem Design Thinking und der Enterprise Architecture kombiniert, um Business Cases für den Einsatz von Generative AI systematisch zu identifizieren, zu entwickeln und zu qualifizieren.

Der Vortrag zeigt, wie spezielle "AI Opportunity Cards" helfen kreative Ideen zu entwickeln. Darauf aufbauend wird gezeigt, wie eine Vielzahl von Design Thinking Tools, darunter Szenario-Formulierungssätze, Use Case Briefs, Customer Journey Mapping, sowie die Bewertung von Geschäftswert und Komplexität, helfen können die Business Cases im Detail zu verstehen. Darüber hinaus werden Methoden aus dem Bereich Enterprise Architecture zur Erstellung von Lösungskontext- und Konzeptdiagrammen sowie Techniken zum Prototyping in verschiedenen Detaillierungsgraden vorgestellt.

Ziel ist es, den Teilnehmern ein umfassendes Verständnis dafür zu vermitteln, wie Generative AI gezielt zur Entwicklung neuer Geschäftsmöglichkeiten eingesetzt werden kann und wie sie diese in ihre Organisationsstrukturen und Strategien integrieren können, um maximalen Nutzen zu erzielen.

TRACK 3: BIG DATA UND ANALYTICS MIT SAP

Gewinnung verlässlicher Informationen durch Datenanalyse

Track Chairs: Prof. Dr. Tobias Hagen, Prof. Dr. Klaus Freyburger

A quantitative questionnaire for SAP-based data analytics in education

F. Eckhard, K. Haug & H. Wittges
Technical University of Munich, Munich, Germany

Abstract: Data analytics is becoming increasingly important in the business world. As a business software leader, SAP is also an essential player in the analytical ecosystem. With the rising interest in big data and machine learning, an increasing number of experts are required to develop analytical systems. This paper presents the results of the questionnaire about the current state and outlook for SAP-based data analytics in education. 40 lecturers from universities worldwide participate in an online survey with three main research questions. What are current and future data analytics topics in education? Which opportunities and challenges exist using SAP cloud services? Which data analytics offerings are used or planned to be used in education? In conclusion, the paper proposes topics for future research and tasks for curriculum development.

Keywords: Education, SAP, Data Analytics, Cloud

1. Introduction

Data analytics is becoming increasingly critical in the business world. (Whitelock, 2018) (Chen, Chiang, & Storey, 2012) With the development of big data, machine learning and, lately, generative AI, experts are increasingly required to develop, maintain, and evaluate analytical systems. Since the demand for data analytics expertise on the job market will grow even bigger within the next few years, universities and academic institutions should incorporate data analytics topics into their curricula. (Baird & Parayitam, 2019) SAP, as one of the leaders in business software, is an essential player in the analytical ecosystem, as a lot of analytically relevant data is already available in the ERP system. (Torii, et al., 2023) Therefore, introducing SAP software to analytical lectures can be an advantage for students building competences which are demanded in the business world. In this paper, we present our survey about the current state of SAP software in analytical curricula and give an outlook on upcoming topics in this area. For the purpose of this study, data analytics refers collectively to traditional data analysis, machine learning, and artificial intelligence.

Specifically, the following three research questions are defined as the objective of the survey:

- *RQ1*: Which business and data analytics topics are currently and perspectively relevant for teaching?
- *RQ2*: Which opportunities and challenges exist in using SAP cloud systems for teaching?
- *RQ3*: Which data analytics tools (SAP and non-SAP) are currently being used and will be used in the future?

This paper is divided into four chapters. Based on the research questions in the second chapter, the methodology for the survey is introduced, specifically the set-up of the questionnaire, the target population, and the pretests. The analysis and interpretation of the questionnaire are presented in the third chapter. Finally the results are summarised in the last chapter and an outlook for further research is given.

2. Research Methodology

This study is based on an online quantitative questionnaire with a range of 25 to 37 questions. The number of questions shown to a participant can vary based on the answers given to some questions. The questionnaire is divided into four question categories:

1) General information about the courses/ lecturers
2) Presently used analytical systems in education
3) Outlook and ideas for the future of analytical systems in education
4) Demographic information about the participants

Five questions are related to the first group, eight to the second group, 20 to the third group and the last group contains four questions.

2.1. Setting

The questionnaire is conducted by the SAP UCC (University Competence Center) Munich. The UCC Munich is an Education-as-a-service provider with customers in more than 21 countries. It is part of the Technical University of Munich and member of the SAP University Alliance. Besides the operation of SAP systems for universities and other academic institutions, creating teaching materials is another important aspect of the SAP UCC's services. (SAP UCC Munich, 2024)

2.2. The Questionnaire

The process described in (Groves, 2011, S. 41ff.) as shown in Figure 1 is followed to develop the questionnaire. (Groves, 2011, S. 42) For the measurement part the research questions described in Chapter 1 are used as a construct and a general guidance during the measurement creation process. The survey is based on open and closed questions as proposed by (Brace, 2013, S. 38). Regarding open questions, open-ended and pre-coded questions are used. For the most closed questions, adding custom information is possible in an open-ended follow-up question in case it is helpful to get more information answering the research question. An ongoing discussion in the research community is the usage of "don't know" responses. (Saris, 2014, S. 106) The author (Saris, 2014, S. 107) highlights challenges such as incomplete datasets and participants opting out to avoid cognitive effort. Other authors have a more optimistic perspective. (Oppenheim, 2004, S. 129) (Ryan & Garland, 1999) (Brace, 2013, S. 46f.) argue "don't know" could be helpful in identifying topics your participants don't know much about or it can lead to new patterns that should be analysed. Lastly (Lietz, 2010, S. 258) notes that the existence of an explicit "don't know" option leads more participants to select it, compared to a questionnaire where the option is not explicitly available. Based on the recommendations, we decided to add an explicit "don't know" option to all questions where it seems like a suitable answer. (Brace, 2013, S. 47) Additionally, only two questions are mandatory. Any other question can be skipped on request.

The questions are displayed in the same order for all participants, because the questions are built on each other logically. To avoid primacy and recency effects in pre-coded open questions, answers are shown in a random order to all participants. This does not generally avoid the problem, but can help spread it more evenly. (Brace, 2013, S. 120)

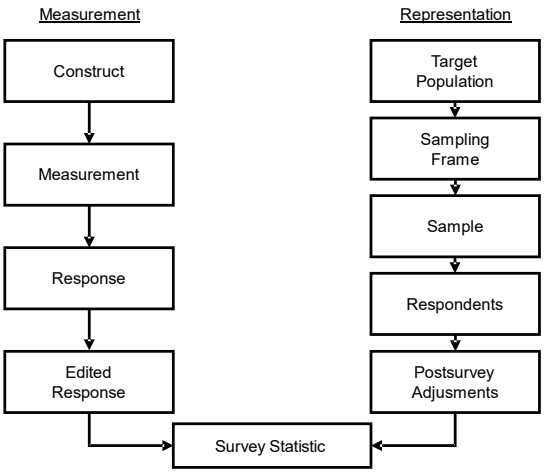

Figure 1: Survey process (Groves, 2011, S. 42)

2.3. Target Population

This survey targets all kinds of university lecturers with a focus on data analytics. There is no difference between lecturers using SAP (UCC) products and lecturers not using SAP products. However, because the SAP UCC has the most contact with lecturers using SAP products, there is an imbalance between SAP users and non-SAP users in the frame population. Nevertheless, extending the population to as many non-SAP users as possible is important for a broad overview of used technologies. All lecturers in the final sample are contacted directly via e-mail with information about the questionnaire. We contacted about 2100 lecturers worldwide. Forwarding the invitation to other lectures was explicitly allowed.

2.4. Questionary Pretests

Pretests are essential in getting feedback and improving the design of the questions and answers. (Bell, 2019, S. 265) (Baur & Blasius, 2022, S. 443) We conducted six pretests, as shown in Table 1. To make sure the questionnaire does not require SAP domain knowledge, we conducted the pretests with persons with and without explicit knowledge on SAP data analytics curricula. We used expert reviews and cognitive interviews as methods in our pretests. (Groves, 2011, S. 260) These two approaches were selected because they appear to be the best output based on the existing resources in this study. The expert reviews are used to ensure that the general questionnaire structure and the questions follow good scientific practices and are suitable for receiving scientific results. The expert reviews were conducted with two post-doctoral researchers. For the cognitive interviews, the Think-Aloud technique is used. These interviews aim to determine if all questions are understandable and whether the given answer options are suitable. Cognitive interviews are performed with three PhD students and one business professional. All pretests are performed as an iterative process, where feedback from a pretest is applied to the questionnaire before the next pretest starts. A shortcoming in our pretest approach is that we did not perform a field pretest. (Baur & Blasius, 2022, S. 446f.)

Table 1: Pretest overview

	With domain knowledge	Without domain knowledge
PhD Student	3 persons	-
Postdoctoral Researcher	1 person	1 person
Business Professional	-	1 person

3. Results

The process proposed by (Groves, 2011, S. 47), shown in Figure 1, is extended by the process advised by (Bell, 2019, S. 165) to analyse the results. The combination is shown in Figure 2.

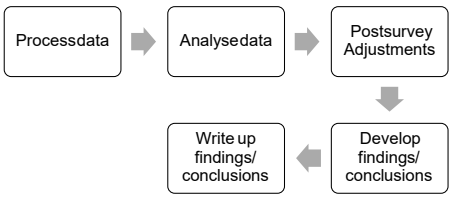

Figure 2: Evaluation process

3.1. Process Data

All in all, 64 people started the questionnaire, and 40 finished the questionnaire completely. The dropout rate is 37,5%, which is slightly higher than expected in the literature. (Cape, Lorch, & Piekarski, 2007) (Brace, 2013, S. 13) Considering that only 10 of the 24 dropout cases proceeded beyond the introductory page, the dropout rate is only 20%, which is below the expected rate. Based on these findings, it can be concluded that the overall design of the questions was of adequate quality, and the preliminary tests were successful.

3.2. Analyse Data and Develop Findings

According to the general and demographic information about the final participants, most participants (87,5 %) already use UCC services. Based on the target population (s. Chapter 2.3), this result is expected, but having 12,5% non-UCC service users in the respondents can give important insights for developing the UCC service offering. Most respondents are professors (57,5%), followed by research associates, lecturers, and lecturers for special tasks, with 10% each. Most participants have at least one data analytics course. Another interesting aspect is that while most courses (70 %) use UCC services, there are still 30% of courses using further software. This remains true even when only UCC service users are selected. 31,5% are using additional software in their courses. The other demographic information is shown in Table 2. Regarding the regional distribution, our study focuses on Europe and, more specifically, Germany, with a share of 55%. Only 2,5% of the participants are based outside of Europe.

Table 2: Demographic information

Country	Share	Institution size	Share	Degree programmes	Share
Germany	55%	< 1000	20%	Computer science	37,5%
Poland	12,5%	1.000 - 5.000	25%	Information Systems	60%

United Kingdom	7,5%	5.000 - 10.000	22,5%	Data Science	30%
Ireland / Portugal	5% / 5%	10.000 - 20.000	25%	Economics	37,5%
Other	15%	> 20.000	7,5%	Other	20%

This is related to the fact that most SAP UCC Munich customers are located in Europe, which is a limitation of this study. Regarding the institution size, the study is well distributed with multiple universities of different sizes. Furthermore, participants from several different disciplines are adequately represented.

RQ1: Topics in Business and Data Analytics

The results regarding the first research question are shown in Figure 3. The integration of ERP systems with data analytics is already used by 52,5% of all lecturers, and an additional 40% are interested in introducing such use cases for their lectures. The integration can be seen as a relevant current and future topic. Two other areas of interest are the combination of SAP technologies with other tools and the offering of independent curricula modules (1 - 2 lecture units) that can be used to flexibly extend courses. For both fields, there is a dominant interest in curriculum elements related to machine learning/ artificial intelligence and data analytics. Other relevant topics like supply chain analytics, data visualisation, and process mining are also being considered.

One particular focus of the questionnaire was the relevance of business process intelligence in teaching. While 80% of participants consider this a relevant or highly relevant topic, only 20% already use an appropriate software solution. Especially SAP Signavio Process Intelligence is currently not very common for people who already use process intelligence software; only 12,5% of participants use Signavio Process Intelligence. The most relevant competitor is Celonis, with a proportion of 50%. This shows that there lies a huge potential in the process mining education tool market and a need to better integrate SAP Signavio into the current SAP teaching landscape.

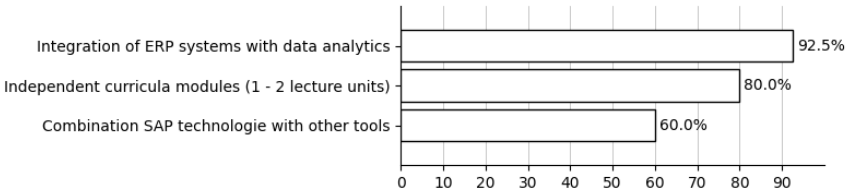

Figure 3: Topics of interest

RQ2: Opportunities and Challenges Using SAP Cloud Systems

The goal of the second research question was to understand the opportunities which SAP cloud systems reveal for teaching and what the challenges are associated with them. In this study, the focus is on SAP Analytics Cloud and SAP Datasphere as SAP cloud solutions for analytics. Because of the increasing trend at SAP to focus on cloud applications, the integration of these systems in the education sector is necessary. (SAP SE, 2024) Based on the survey results, 40% of the lecturers haven't considered cloud opportunities yet, but 50% acknowledge at least a few opportunities to use the cloud. From a more detailed perspective, the most favoured opportunity is the removal of tool installations (browser only). This is especially true for SAP Analytics

Cloud and SAP Datasphere, but only partially for SAP HANA, which has an already integrated web interface into the on-premise version.

Regarding the cloud challenges, nearly 50% of the participants don't see any challenges, and another 25% haven't thought about them yet. For the rest, the challenges mostly concern performance issues, support problems and open questions regarding pricing/ licensing. The SLA-level and scope differences between SAP business support and UCC support is an open issue and reinforces the need for comprehensive UCC support for universities. The issues regarding licensing and pricing remain, but there are already offers via the UCC that can solve this problem. A possible explanation for the low number of challenges seen could be, besides the fact that there may not be many challenges, the low saturation of the product in the education market. Like with all kinds of software, reliability is a characteristic that needs to be measured over time. (Wohlin, Höst, Runeson, & Wesslén, 2003, S. 25) The low saturation is also visible in the questionnaire. Only 2,5% already use an SAP cloud product in their lecture, and many lecturers are unaware of the SAP cloud services (80% SAP Datasphere/ 42,5% SAP Analytics Cloud). For a successful cloud transition, requirements related to the UCC were queried. The results are shown in table Table 3. The requirements A, C and D are partially related to the observed challenges and important aspects that need to be considered by SAP and UCC for a successful cloud transition. B and E are aspects that already play an important role at the UCCs and remain important in cloud environments.

Table 3: UCC cloud requirements (multiple choices possible)

Category	Results
(A) Fixed and predictable costs	60%
(B) Support for problems and challenges in teaching	50%
(C) Support for problems and challenges with the technology	52,5%
(D) Administration of the cloud environment	55%
(E) Providing teaching materials	77,5%
I have no special requirements	5%

RQ3: Data Analytics Offerings (SAP and non-SAP) Currently Being Used and are to be Used in the Future

As mentioned in Chapter 1, SAP is a global leader in business software, but the analytics market seems more fragmented, and the tool usage in education is unclear. Therefore, multiple questions in the questionnaire focus on the tool usage in education. Regarding SAP software, the most used product is SAP HANA (25%), followed by SAP Analytics Cloud (15%), but 37,5% of the lecturers aren't using any SAP analytics software right now. The results for non-SAP software are shown in Figure 4. The majority of lecturers are using Excel 52,5% followed by Python and R

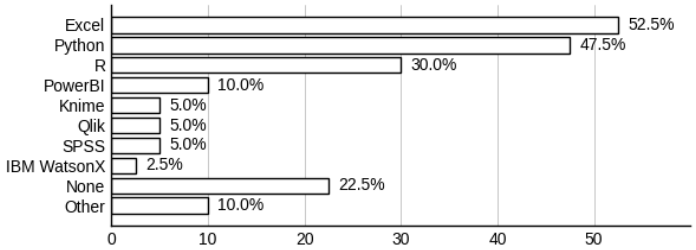

Figure 4: Non-SAP tool usage in education

with 47.5% / 30%. The wide usage of Excel is not surprising because it's one of the standard tools in business analytics and a good starting point for data analytics and visualisation. Also, using Python and R seems plausible because both tools are free of charge and offer a wide number of libraries (e.g. scikit-learn, numpy, matplotlib, keras) which are suitable for beginner and advanced courses. Besides these tools many other smaller products are also used in education, but there is a clear focus on Excel, Python and R. This trend could become even stronger in the future. 47,5% of participants plan to add new non-SAP products to their lectures. Excel, Python and R account for ~73% of this share, with other tools playing a subordinate role. The only exception is PowerBI, which is already used by 10% and has a share of ~11% of new introductions. PowerBI is also free of charge and offers no-code visualisation options, which could be easier to use than Python or R, depending on the course requirements. An open research question is how SAP products can make a difference in this tool environment. Either as completely independent tools or as an addition to the existing landscape.

4. Conclusion

This study conducts a questionnaire about SAP-based analytics in education with three research questions. Concerning the most relevant topics in business and data analytics, one important finding is the interest in more extensive integration of ERP systems with analytical software. This can be used as a starting point for further curricula development and can be a unique feature offered by SAP in education. Independent curricula modules, which flexibly extend various curricula, are a valuable finding too. An important result about the opportunities and challenges of using cloud services is the low saturation of SAP cloud products in education. Many lecturers are unaware of the cloud offering and have not invested time considering the opportunities and challenges of using a cloud product. It is the task of the SAP UCC to clarify open questions with SAP and provide a suitable offer for cloud products in education. Using free-of-charge software like Python, R, and PowerBI is an educational trend.

In summary, this paper contributes to ongoing research on integrating SAP (analytical) software in education. Based on the information offered by this questionnaire, multiple new tasks and research questions arise. For SAP and SAP UCC, an ongoing question is how to integrate Cloud software successfully in education. Especially the licensing topic is a current issue. From an educational perspective, the insights about current topics and tools can be used as a starting point for further research. For example, developing small independent curricula modules for different knowledge levels and tools in integration with SAP services.

The main limitation of this study is the target population used. While the authors tried including non-SAP UCC customers in the survey, most participants are SAP UCC customers. In future studies, more effort is necessary to get a broader questionary sample. The other limitation is the sample size of 40 participants. Although the participants were distributed internationally (with

a focus on Europe) from universities of different sizes and with different research fields, a larger overall sample would be more expedient. Nevertheless, we see our questionnaire as a good starting point, which we will continue with further interviews.

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Identification of Process-relevant Data Fields Based On SQL-Tracing for Enhanced Business Process Analysis

Steffen Meeuw, Carl von Ossietzky Universität Oldenburg, Germany
Marc Schmeyers, René Kessler, abat AG, Germany
Jorge Marx Gómez, Carl von Ossietzky Universität Oldenburg, Germany

Abstract: Process mining, a crucial sub-discipline of data science, enhances the understanding and optimization of business processes through event-related data analysis. The utilization of data from systems such as Enterprise Resource Planning (ERP) and Customer Relationship Management (CRM), to create accurate event logs is fundamental but challenging due to manual processes. While SAP systems manage various business processes, the reliance on predefined templates from providers like Celonis and Signavio restricts flexibility, as these templates cover only a limited number of processes and requiring manual adjustments for customized processes. This paper proposes a novel approach for creating event logs using SQL-Tracing in SAP systems, systematically identifying and linking relevant SQL statements to form a comprehensive extraction pattern, reducing the need for expert knowledge and making process mining more accessible. We discuss the methodology's design, challenges, and practical implications, suggesting future enhancements for real-world applicability and further automation.

Keywords: Process Mining, Event Log, SQL-Tracing, Business Process Analysis

1. Introduction

The field of process mining, a sub-discipline of process science, is fundamentally concerned with methods for analyzing event-related data in order to improve the understanding of business processes (van der Aalst, 2016). This is mainly realized through the use of information systems, such as Enterprise Resource Planning (ERP) and Customer Relationship Management (CRM) systems, which are repositories for all process-related data. The creation of an event log, a step that underpins all subsequent analyses and insights they provide, is a central element of process mining. The completeness and accuracy of the data used in the event log is crucial, making this phase one of the most time-consuming and manually intensive in most mining projects (Stein Dani *et al.*, 2022).

SAP ERP systems are a prevalent choice for managing a variety of business processes (Lu *et al.*, 2015). Currently, commercial providers such as Celonis and Signavio offer predefined templates for a limited number of processes, which simplify data extraction by specifying the tables and fields to be extracted (Celonis 2024, Signavio 2024a). However, if the business process deviates from these templates, additional fields must be manually integrated into the event log. This task, while not laborious when altering existing templates, becomes substantially complex when no template exists. The latter scenario is commonplace as templates are currently available for a few processes, excluding key operations like inventory management, financial planning, accounting, and production control processes (Celonis 2024, Signavio 2024a).

In cases without a predefined template, identifying the necessary tables before extraction becomes a daunting task, particularly in complex systems like SAP ERP, which comprises approximately 800,000 tables with numerous ambiguous relationships (Weber *et al.*, 2022).

We propose to automate the steps necessary for event log creation, proposing a novel methodology that diverges from traditional approaches, which rely heavily on expert knowledge and relational models (Berti *et al.*, 2022). Instead, it leverages SQL-Tracing to automatically identify all process-relevant information during each step within an SAP system. By discerning and linking relevant SQL statements to form a comprehensive extraction pattern, this paper contributes to the field by potentially lowering barriers to entry for businesses wanting to adopt Process Mining methodologies, ultimately facilitating a broader understanding and enhancement of business processes.

In this paper, we first present important preliminary work from the field of event log analysis for determining process-relevant data, differentiate ourselves from existing approaches and explain our methodological approach. We then introduce our novel technical approach for identifying process-relevant data fields via SQL-Tracing, which we then demonstrate in case studies using a best-practice process and a customized process. Finally, we discuss the results presented and give an outlook on future research activities.

2. Related Work

The creation of event logs traditionally relies on predefined templates from tools such as Celonis and Signavio, which facilitate data extraction by specifying the necessary tables and fields (Celonis 2024, Signavio 2024a). However, these templates only cover a limited range of processes. Deviations from the templates require manual integration of additional fields, a process that is both labor-intensive and prone to errors. Recent advancements include the use of object-centric event logs to determine relevant tables for process mining. Berti et al. (2022) proposed capturing interactions between business objects to identify pertinent tables within ERP systems. While this method is innovative, it does not extend to extracting specific process-relevant fields, including custom fields, which are often crucial for detailed analysis.

To address these limitations, our research proposes a novel methodology using SQL-Tracing to automate the identification and extraction of process-relevant data fields within SAP systems. SQL-Tracing monitors and records SQL statements executed during process runs, thereby revealing which tables and fields are accessed. This approach allows for the systematic identification of process-relevant fields, reducing reliance on expert knowledge and reduces manual intervention. By automating the core stages this process, our methodology enhances the accessibility and efficiency of Process Mining. Our approach goes beyond existing methods by providing a more detailed and automated extraction of data fields, addressing a significant gap in the current Process Mining techniques.

3. Research Design

To develop our proposed methodology for event log generation through SQL tracing, we use the action research methodology, because it "aims to solve current practical problems while expanding scientific knowledge" (Baskerville and Myers, 2004). In action research, we, as researchers, actively engage and intervene to achieve practical solutions (Robra-Bissantz and

Strahringer, 2020). Our process model, conceptualised as an artifact from a design science research (DSR) perspective (Hevner *et al.*, 2004), requires close collaboration with practitioners, in line with the principles of action design research (ADR). ADR typically encompasses three phases: building, intervention, and evaluation (Robra-Bissantz and Strahringer, 2020). This approach facilitates a robust integration of scientific inquiry and practical applicability and addresses the critical need to translate data mining processes from research to practice.

4. SQL-Tracing for Identification of Process-relevant Data Fields

In our technical approach, we utilize SQL-Tracing within SAP systems to identify process-relevant data fields, which are crucial for subsequent process mining and analysis. To analyze a process effectively, it is crucial to first identify the locations of the data to be analyzed. For instance, to calculate the total revenue of a company, it is essential to know where the revenue data of individual orders is stored. Once this information is available, the revenue of individual orders can be summed to the total revenue. Therefore, the first challenge of any analysis is to identify the data relevant to the analysis.

The following concept addresses this challenge by locating the storage of data generated during a process run. The goal is to create a pattern that includes the fields and tables used in the process. As illustrated in Table 1, this pattern must list table and field names. During the execution of a process in an ERP system, the information to be later evaluated is generated at the moment the process is executed. This means that when a process step is carried out, the information of this step is written to the database. This precise moment contains all the information relevant for subsequent analysis, as this is when the data to be analyzed later is generated. The core idea of our approach is to use the communication of the SAP system with the database to create a pattern for further analyses.

Tab. 1: Example for the Extraction Pattern

Table	**Data Fields**
VBAK	*MANDT, VBELN, ERDAT, ERZET, ERNAM, MANDT*
VBAP	*VBELN, POSNR, MATNR, MATWA*
...	...

The steps of our technical approach are shown in the flow diagram in Figure 1 and explained step-by-step in the following:

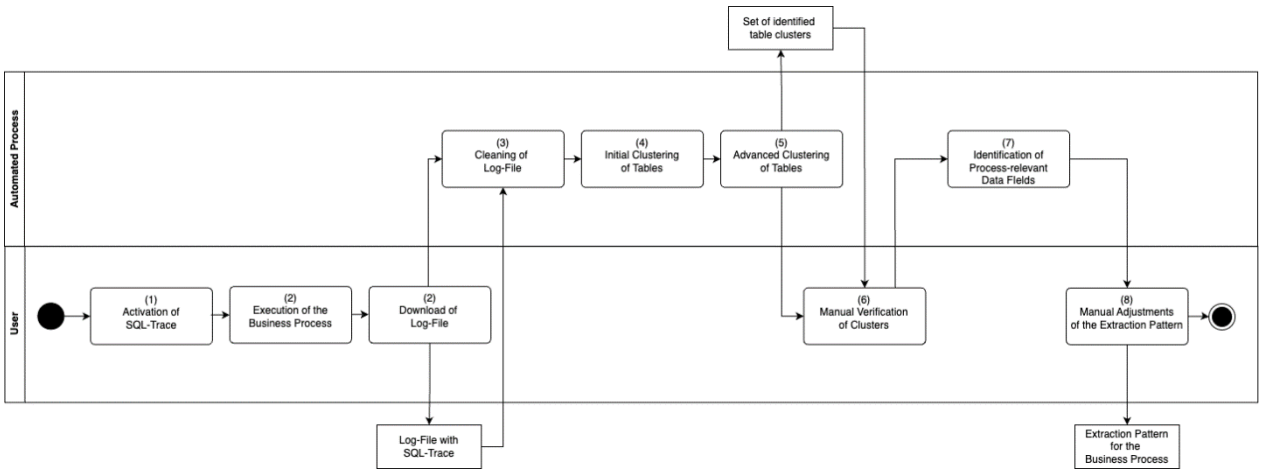

Fig. 1: Overview of the Technical Approach for the Generation of Extraction Patterns

(1) Activation of the SQL-Trace: By activating the SQL-Trace, the communication between the SAP system and the database can be monitored during the process flow. This is achieved by using the SQL-Trace function provided by SAP, which can be accessed via the SAP system transaction "*ST05*". Once activated, the trace logs all communication between the SAP system and the database. In particular, we will focus on the *INSERT* statements, since they contain all the information about the tables and therefore their structure can be traced at the data field level.

(2) Execution of the Business Process & Log-File Download: To create an extraction pattern, the business process must be executed, and the log file subsequently downloaded. This log file contains information on what occurred in the database during the process run. This includes the SQL statements executed on the database, the name of the table to which the data is being extracted, the name and username of the user who initiated the communication, the transaction that was executed, and other technical details irrelevant to the concept's implementation. To create an extraction pattern that is as complete as possible, care must be taken to ensure that all variants of the business process are run. For example, as well as running through the "Order to Cash" process, scenarios such as canceling an order should also be considered so that the data fields used for this scenario variant can be identified later.

(3) Cleaning of the Log for Analysis: Once the SQL-Trace has been generated and downloaded, it must be filtered in order to exclude non-process-relevant information. This is achieved by removing irrelevant data based on the user ID and business object numbers generated during the process run. Only INSERT statements are considered, as these are required for identifying process-relevant fields.

(4) Initial Clustering of Tables: The initial clustering process identifies relations between the tables. Following the application of a filtering criterion, each remaining table in the dataset is subjected to a further examination to ascertain its relations to other tables in the dataset. Each table commences as an initial cluster, and tables related to it are subsequently incorporated into this cluster. Finally, a check is made to see if identical clusters were created. If this is the case, these clusters will be removed before the end of the phase, so that only unique clusters are left.

(5) Advanced Clustering of Tables: The advanced clustering step is an iterative process that refines the clusters by assigning tables to an overarching cluster. This is done by iterating through each cluster and applying the clustering method again. This helps to structure the data into a more coherent and logical form, aligning related tables together. This step forms the basis

of the extraction pattern and produces a set of identified clusters that may be suitable for further processing.

(6) Manual Verification of Clusters: At this stage, it is necessary to have a manual process in place to determine which clusters should be retained for further processing. This ensures that only relevant clusters are considered, and that the analysis focuses on important data sets. Although an expert is required for this, the requirement profile of this expert is different from previous approaches such as Berti et al. (2022). In our approach, the expert only has to select one cluster from a set of clusters to be used in the further process. For instance, in the case of many technical or system tables, the corresponding cluster can be excluded due to low relevance for the process.

(7) Identification of Process-relevant Data Fields: The INSERT statements from the filtered SQL trace are analyzed in conjunction with the function module *"RFC_READ_TABLE"*. This analysis identifies the fields in the respective tables that are populated during the process run. Any fields that do not contain values are discarded, thereby streamlining the dataset to include only the most relevant data fields.

(8) (Optional) Manual Adjustment: Any necessary manual adjustments are made to the extraction pattern to add or remove fields or tables. This step ensures that fields serving as markers (e.g., a field marking a document as voided) are not omitted if they did not occur in the initial run.

5. Demonstration

To assess the efficacy of the procedure described in the preceding section, two case study scenarios were conducted. In the first scenario (Scenario 1), the standard process "*Sell From Stock (BD9)*" was compared with an available Signavio template (Signavio 2024b). The objective of this scenario was to ascertain that all process-relevant fields were correctly identified through the technical approach presented, thereby providing evidence of the approach's general suitability. In contrast, in the second scenario (Scenario 2) we intended to verify whether all newly added fields can be identified within a customized process, namely the "*Create Billing Documents (VF01)*".

Scenario 1: Comparison with existing Signavio Templates - The solution was able to identify 100% of the process-relevant tables for the best practice process "*BD9 – Sell from Stock"* in comparison to the Signavio template for the "*Order to Cash*" process. Additionally, 80% of the process-relevant fields were recognized. The remaining 20% of the fields that were not recognized were those that were not utilized in the process run. This implies that the functions responsible for write access to these fields were not called. For instance, no sales order was employed as a template, thus the requisite fields for this function were not populated and could not be identified as process-relevant. Table 2 illustrates the unrecognized fields and provides an explanation of why they were not included in the analysis by our procedure. The majority of the fields are date or time stamps, which were not set because the functions were not called.

Tab. 2: Overview of Unrecognized Fields in Scenario 1 compared to the Signavio Template (Signavio 2024b)

Table: Fields	Type of Fields & Reasons for Non-Consideration
ACDOCA: BLDAT, BUDAT **BKPF**: AEDAT, UPDDT, BSEG: ZFBDT **BSEG**: AUGGJ **LIKP**: AEDAT, KOUHR, LFUHR, WADAT	Fields with date or time stamp. As these functions were not carried out during the process run, no time or date stamps were generated.

LIPS: AEDAT **VBAK**: AEDAT, VBAP: AEDAT, WAUHR **VBEP**: MBUHR, EZEIT **VBFA**: AEDAT **VBRK**: AEDAT	
ACDOCA: BSCHL, BLART, BUZEI	Field in which a document key or the document type is stored, specifies the item in a document
ACDOCA: AUFNR, KDAUF, KDPOS, NETDT	No Customer Order was used.
ACDOCA: KOART, UMSKZ, ZUONR	No Account Type was specified. No Turnover Indicator was used. No Allocation Number was used.
BKPF: FRATH	Indicator Field was not used.
BSEG: ZBD1T, ZBD2T, ZBD2P, ZBD1P, WSKTO, ZBD3T, SK1DT, SK2DT	Discount was not used.
BSEG: MANSP, MANST, MABER, MADAT	Dunning block was not used.
LIKP: VSART	No Shipping Method was selected.
LIPS: LGNUM, LIPS: DLVTP	Stock Number, Delivery Type was not used.
VBAK: VKBUR, VBAK: LIFSK, FAKSK, AUGRU	Sales office, delivery block, billing block, order reason was not specified.
VBAP: VGPOS, VGBEL, ABGRU	Closed item template, template document, change reason.

Scenario 2: Customization of "Create Billing Documents (VF01)" - The efficacy of this approach has been demonstrated in the case of processes that have been customized and therefore expanded to incorporate custom fields. This was accomplished by applying the methodology employed in process *VF01* to the table VBAP, incorporating the fields *ZZ_PERNR, ZZ_FAKTSPLIT* and *ZZ_KOSTL*. The resulting process was then executed, and the SQL-Trace analyzed. The results demonstrated that 100% of the additional fields were correctly identified and incorporated into the extraction pattern.

6. Discussion

The demonstration of our previously presented technical method shows that the process-relevant fields can be determined for individual processes by analyzing the SQL-Trace. The data fields that cannot be determined by analyzing the write accesses to the database are, in most cases, timestamps or other flags that are written by *UPDATE* statements. Since we only analyze write accesses to the database (*INSERT* statements) in our presented technical method, those fields could therefore not be identified as process-relevant. This implies that all business objects that could occur in the individual process variants must be created so that complete coverage of all process-relevant fields can be guaranteed. Nevertheless, our presented procedure was demonstrated to be flexible enough to be used with tables that do not correspond to the SAP standard. As the custom fields are also present in the INSERT statements for customized processes, these could be identified as process-relevant, thus enabling an individual subsequent downstream process analysis to be conducted on this basis.

7. Conclusion and Future Work

In this paper, we introduced a novel, technical approach for event log creation in Process Mining, shifting away from the traditional reliance on expert knowledge and relational models (Berti *et al.*, 2022). By leveraging SQL-Tracing within ERP systems, it systematically identifies

and links essential process data, simplifying the event log creation process. The automation reduces the need for manual intervention and expert consultation, making Process Mining more accessible and cost-effective. This approach not only facilitates a broader adoption of Process Mining but also enhances business process understanding and optimization. However, future work could focus on further automating additional steps in the event log creation process and operationalizing the prototype to enhance its application in real-world settings. As our approach to date has focused solely on INSERT statements derived from SQL-Trace data, it is possible to extend this analysis to include UPDATE statements. The inclusion of UPDATE statements would allow additional fields to be identified, such as date and time stamps, which could then be subjected to further process mining techniques. An additional potential extension would be to provide assistance in generating the event log based on the process data from the SQL-Trace. A further potential extension could also be the providing of assistance in the generation of the event log, based on process data from the SQL-Trace. This would make process mining more accessible, efficient, and comprehensive, paving the way for improved business process analysis and optimization.

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TRACK 4: ENVIRONMENT SOCIAL GOVERNANCE (ESG), KREISLAUFWIRTSCHAFT UND NACHHALTIGKEIT

Track Chairs: Prof. Dr. Jorge Marx Gómez, Prof. Dr. Uta Mathis, Prof. Dr. Hans-Jürgen Scheruhn

Strategic Integration of Value Driver Networks and Causal Inference in Prescriptive Business Analytics

J. Marx-Gómez, M. Mattern, A. Solsbach
Carl von Ossietzky Universität, Oldenburg, Germany

Abstract: This paper presents a student project group's solution integrating value driver networks and causal inference using SAP HANA and SAP Analytics Cloud (SAC). The solution quantifies causal relationships based on directed acyclic graphs (DAGs), enabling the holistic management of financial and non-financial key performance indicators (KPIs) under regulatory and market pressures. Employing Pearl's do-calculus and Bayesian networks facilitates descriptive, diagnostic, predictive, and prescriptive analytics, enhancing strategic decision-making in hybrid management/sustainability control systems (MCSs/SCSs).

Keywords: Causal Inference, SAP HANA, Prescriptive Analytics, Sustainability, Bayesian Networks

1. Introduction

Since January 2023, German companies must comply with the "Supply Chain Act" (Bundesministerium der Justiz 2021), requiring regular reporting and preventive measures for human rights and environmental issues. From January 2024, the Act extends to companies with at least 1,000 employees. This law marks a shift from *voluntary* to *mandatory* sustainability reporting and from *disclosing* to *managing* sustainability-related accomplishments. Similarly, the EU's Corporate Sustainability Reporting Directive mandates compulsory standards and audits ("limited assurance" or "reasonable assurance" as a first step) (Directorate-General for Financial Stability, Financial Services and Capital Markets Union 2024).

However, regulations are not the only factor pushing companies to focus on sustainability-related objectives because non-financial outcomes increasingly impact financial outcomes:

- Poor sustainability performance limits access to certain capital markets. Some investors only invest in companies listed on sustainability indexes like the Dow Jones Sustainability Indices (S&P DOW JONES INDICES LLC (S&P DJI) 2024) or the FTSE4Good Index Series (London Stock Exchange Group plc 2024).
- Pursuing sustainability goals can influence financing costs through green loans or bonds, impacting net income.
- Environmental issues cause risks related to indemnity claims, which affect credit ratings and, thus, financing costs and net income.
- Government measures like the EU Taxonomy Regulation and the EU Green Deal influence critical success factors and financial KPIs.

Managing financial and non-financial targets holistically involves understanding the interplay between interventions and outcomes from financial and non-financial domains. Traditionally, value driver trees based on value-based management (VBM) theory (Rappaport 1986) like in SAC (SAP SE 2024a) or value driver networks (Lanzinner et al. 2008) have been used to visualize such dependencies or to make predictions (Valjanow et al. 2019). While already researched regarding sustainability (Alattyih et al. 2019, Patalas-Maliszewska et al. 2022),

VBM needs reexamination from a sustainable governance point of view (Wobst et al. 2023), becoming even more complex when integrating shareholder, stakeholder, and sustainability values across diverse domains, locations, and points in time. Fig. 1 illustrates this challenge:

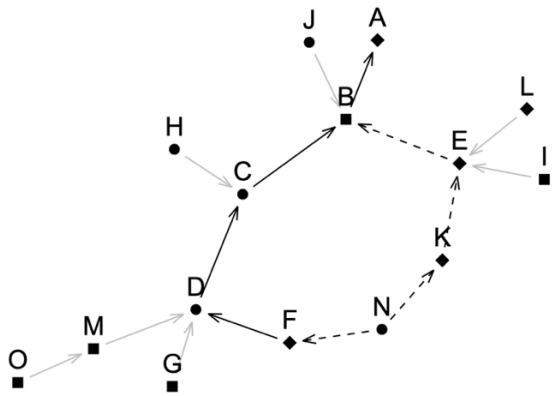

Fig. 1: Schematic representation of a random value/sustainability driver network (Barabási–Albert algorithm, directed edge from N to K added to create biasing path, Fruchterman-Reingold layout). Nodes represent KPIs, different shapes of nodes indicate that they originate from different control systems (domains), all directed edges represent statistical associations, solid black ones represent causal relationships, and dashed ones refer to biasing paths.

The increasing importance of non-financial KPIs is addressed by creating SCSs like SAP's Sustainability Control Tower (SAP SE 2024b), but in the long run, the above challenges can only be met by *integrating* SCSs and MCSs (Gond et al. 2012). The resulting hybrid control systems are, however, characterized by high levels of heterogeneity and – due to a higher number of relevant variables – are also more likely to be affected by epistemic and ontological uncertainty, leading to frequent changes as sustainability regulations and requirements evolve:

1. *Heterogeneity*: Multinational corporations deal with diverse KPIs and local interventions that can have global, time-lagged, or path-dependent knock-on effects. These effects often affect regulatory thresholds that are, again, time-period specific.
2. *Uncertainty*: Unforeseen legal requirements and environmental shocks – health crises, conflicts, and geopolitical changes – trigger paradigm shifts, altering the relevance, importance, and interrelationships of KPIs.

In Gartner's "Analytics Ascendency Model" (Whitlock Strickland 2022), descriptive analytics examines *what happened*, diagnostic analytics tries to find out *why it happened*, predictive analytics tries to foresee *what will happen*, and prescriptive analytics attempts to work out what to *do* to *make something happen*. Whereas business intelligence (BI), algorithmic induction, or AutoML support organizations by automating and therefore speeding up the design and adaptation of value driver networks and overcoming organizational blindness caused by existing yet obsolete "theories" (Felin & Zenger 2017), *prescriptive* analytics and hence conscious (*do*-)interventions can only be evaluated if (often probabilistic) *causal* relationships are understood.

In terms of probability theory, this means that we need the conditional probability distribution $\vec{P}$ of three (disjoint) random vectors $\vec{X}$ (*do*-interventions) and $\vec{Y}$ (outcomes) and $\vec{Z}$ (adjustment set). Adjustment sets are groups of confounding variables that must be controlled for when isolating causal effects; they can be identified using `dagitty::adjustmentSets`. Each $P_{i,j,k}$ in $\vec{P}$ stands for the probability that a specific realization $\vec{y}_i$ of a random vector $\vec{Y}$ occurs if

intervention $\vec{x}_j$ is chosen under assumed constraints $\vec{z}_k$ – that is, assumed realizations of confounding variables – with $\vec{x}_j$, $\vec{y}_i$, and $\vec{z}_k$ belonging to the sample spaces Ω_X of $\vec{X}$, Ω_Y of $\vec{Y}$, and Ω_Z of $\vec{Z}$ respectively. Pearl (Pearl 2000) expresses the difference between statistical association and causation by using the so-called *do*-operator, see formula 1:

$$\vec{P} = \left[P_{i,j,k}\left(\vec{Y} = \vec{y}_i \mid \mathbf{do}\left(\vec{X} = \vec{x}_j\right), \vec{Z} = \vec{z}_k\right)\right], \quad \forall \vec{y}_i \in \Omega_Y, \forall \vec{x}_j \in \Omega_X, \forall \vec{z}_k \in \Omega_Z \tag{1}$$

In the context of a student project group and supported by our research partner, the Oldenburg-East Frisian Water Board ("Oldenburgisch-ostfriesischer Wasserverband" (OOWV) (Oldenburgisch-Ostfriesischer Wasserverband 2024), we implemented a tool supporting the detection and quantification of causal effects as part of a descriptive, diagnostic, predictive, and prescriptive analytics workflow in an SAP environment.

We used a variety of data sources (COVID data (Hale et al. 2023), capital market data (retrieved via RapidAPI's Yahoo Finance API (Yahoo Finance 2024), and IT ticket data supplied by OOWV) to demonstrate the versatility of our work; but our main goal was finding and testing a generalizable approach supporting the automated detection and quantification of causal effects across different domains, thereby contributing to the Sisyphean task (Elkington 2018) of integrating MCSs and SCSs.

2. Methodology

In 2023 and 2024, a project group named *MARVIN* – "*M*anagement "*Ar*chitectures, "*V*UCA, Causal "*In*ference" – consisting of six students at Carl von Ossietzky Universität Oldenburg worked on developing and implementing a tool supporting the visualization and quantification of causal effects. Key tools used by the project group were DAGs, Bayesian networks, and R implementations of Pearl's (Pearl 2000) back-door criterion (Textor et al. 2017) – to determine adjustment sets – and of the do-calculus (Tikka & Karvanen 2017), with the latter being used to estimate joint probability distributions and hence average treatment effects (ATEs).

A value driver or KPI network like the one shown in fig. 1 is a DAG and can hence be treated as a Bayesian network. To learn the structure and weights of that Bayesian network, we used observational time series data stored in a data warehouse in a standardized format; with Bayesian networks implicitely representing the joint conditional probability distribution $\vec{P}$ of their nodes, they can be used to predict the joint probability of certain events. Using formula 1, the DAGs structure and weights would, however, have to be learned based on data collected in a randomized controlled trial in which different "groups" are exposed to different possible treatments or interventions x_j. In contrast, the do-calculus enables the estimation of the joint probability distribution – or the joint conditional probability density function $f_{\vec{Y}|\vec{X},\vec{Z}}\left(\vec{Y}|\mathrm{do}\left(\vec{X}\right), \vec{Z}\right)$ in the case of continuous random vectors – based on purely observational data. The algorithm accomplishes this by eliminating the do-operator from formula 1. For example: If we wanted to calculate the ATE $ate(f_1, f_2)$ – that is, the change in the probability of outcome $A = a_i$ caused by choosing intervention f_1 over f_2 for a given realization $[e \quad k \quad n]$ of adjustment set $[E \quad K \quad N]$, we could use formula 3 (which only needs observational data) instead of formula 2:

$$\begin{aligned} ate(f_1, f_2) = P(A \quad &= a_i \mid \mathbf{do}(F = f_1), E = e, K = k, N = n) \\ -P(A \quad &= a_i \mid \mathbf{do}(F = f_2), E = e, K = k, N = n) \end{aligned} \tag{2}$$

$$ate(f_1, f_2) \quad = \sum_{l,m,n} P\,(A = a_i|b_n)P(b_n|n, f_1, k, e, d_l, c_m)P(c_m|d_l)P(d_l|f_1) \\ - \sum_{l,m,n} P\,(A = a_i|b_n)P(b_n|n, f_2, k, e, d_l, c_m)P(c_m|d_l)P(d_l|f_2) \tag{3}$$

Formula 3 was determined using `causaleffect::causal.effect` with simplification and pruning and d-separation to drop I and L from $P(B|I, L, N, F, K, E, D, C)$.

3. Implementation, Results and Lessons Learned

Working with data from different domains, some of which were supplied by OOWV, we built a solution to both manually build and automatically generate KPI networks and identify the causal effects of selected KPIs ("interventions") on others ("outcomes"). Ticket data were stored in SAP HANA 2.0, express edition 2.0 SPS 07, and other data (such as trained models) in a proprietary PostgreSQL database. The front end (a DAG editor) was based upon Vue.js, the server on FastAPI. Due to performance requirements – especially with machine learning algorithms –, Celery, RabbitMQ, and redis were used for load balancing and asynchronous processing.

Our descriptive analytics relied upon simple visualizations of the data (line charts, scatterplots), pairwise correlations (heatmaps), and learned random forests (feature importance plots, uniform manifold approximation, and projection plots) in SAC (embedding R code for specific diagrams when required) plus Microsoft Power BI. For diagnostic analytics, we used R's `bnlearn` package and, more specifically, `hc` (Hill Climbing), `h2pc` (Hybrid HPC), `mmhc` (Max-Min Hill Climbing), and `tabu` (Tabu Search) with blacklists and whitelists, `bn.cv` (weight learning with loss-likelihood loss and 5-fold cross-validation); R was running on a separate virtual machine for scalability and integrated as suggested by SAP (SAP SE 2018). Additionally, we also trained random forest models using package caret. As we again used 5-fold cross-validation and worked with around 1,500 variables (after hot-encoding), the respective jobs were executed on our university's Multi-Purpose-Compute-Cluster ROSA.

Based upon the DAGs that were either manually created by the user (in which case only the weights had to be learned) or automatically learned from the data and the interventions and outcomes specified by the user, we used function `adjustmentSets` from R package `dagitty` to identify adjustment sets and `causal.effect` from R package `causaleffect` with simplification and pruning to derive expressions corresponding to formula 3 using `causal.effect`. To simplify the task to be handled by the project group, we did not consider counterfactuals and unobserved confounders. Conditional probabilities, like in formula 3, were estimated using Monte Carlo simulation with at least five million samples.

The predictive accuracy of the Bayesian networks was rather poor (around 0.3 with a no-information rate of 0.1, using 80% of the data for training and 20% as test data), thus limiting the informative value of the identified causal effects. With random forests, we were able to accomplish higher, though still relatively low, accuracies of about 0.5). This was, however, a data-related issue (see section 3.).

As stated in section 1, the main objective of our project was not to gain insights from specific data but instead to identify areas for improvement based on OOWV's feedback to then suggest and test a versatile, generalizable approach to help organizations model and quantify causal effects in hybrid (shareholder value, stakeholder value, and sustainability-oriented) KPI

networks. The data models we used in HANA were designed for maximum flexibility so that swapping KPIs was not an issue. Four areas for further research emerged:

1. *Data*: The IT ticket data we mainly used for test purposes were not ideal from a causal inference perspective; they contained information about tickets at closing time but no intermediate snapshots, making it hard to formulate before-after (causal) hypotheses. Furthermore, key information (such as service desk capacity) was unavailable for data protection reasons, suggesting that relevant confounders were missing.
2. *Formulation of causal hypotheses*: The search space for statistical associations is enormous. If the cardinality $|\vec{X} \cup \vec{Y}| = |\vec{X}| + |\vec{Y}| = n$, there are $B(n) = \sum_{k=1}^{n} S\,(n,k)$ ways to split $|X \cup Y|$ into subsets for feature engineering with $S(n,k)$ being the Stirling number of the second kind. And there are $n!$ topological orderings of components (= KPIs) of $\vec{X}$ and $\vec{Y}$, for each of which there can be $2^{\binom{n}{2}}$ variants of DAGs, though many of them ($\sum_{k=1}^{n-1}\binom{n}{k} 2^{\binom{n-k}{2}}$) contain unconnected nodes; with our example in fig. 1, we are, however, still dealing with $2^{105} - \sum_{k=1}^{14}\binom{14}{k} 2^{\binom{14-k}{2}} \approx 4 \times 10^{31}$ potential DAGs. The combinatorial explosion also produces many irrelevant DAGs containing directed edges from effects to causes or violating common sense and/or domain knowledge.
3. *Bayesian networks*: When learning the structure of Bayesian networks from hot-encoded discrete data, the system soon runs out of memory. This limitation is due to the high-dimensional nature of the data and the computational complexity involved in processing and storing large joint probability tables, which are essential for accurate network learning.
4. *Computing power*: Substantial computing resources are required when using other machine learning tools, such as random forests, which creates the need to integrate high-performance computing environments even with in-memory databases like SAP HANA.

4. Conclusion and Future Research

There are, however, several ways to deal with the above issues:

1. *Data*: We have started to develop a reference architecture for SAP Datasphere/HANA to support classical and new value driver networks and automate interactive controls (Simons 1995) through standardized virtual data models and through refining the definition of hard and soft business rules (Linstedt & Olschimke 2015).
2. *Formulation of hypotheses*: We are now reducing the number of DAGs by including validity periods and ensuring non-overlapping periods for potential causes and effects. Furthermore, we are starting to use an LLM (ChatGPT-4 Turbo) fine-tuned with domain knowledge and metadata on the KPIs in $\vec{X}$ and $\vec{Y}$ to identify valuable causal relationships.
3. *Bayesian networks*: The relatively poor predictive power of our Bayesian networks may be due to the hyperparameters (structure learning algorithm, scoring metric) we chose with `bnlearn` and `bn.fit`/`bn.cv`, but nevertheless, we accomplished much better results with – for instance – random forests. On the other hand, calculating conditional joint probability distributions using the formulae provided by `causal.effect` but then random forests to estimate the terms in these formulae raises consistency-related issues. We are currently looking at options in which Pearl's concept can be aligned with probabilities that are not solely based upon DAGs (such as via feature engineering).

4. *Computing power*: An HPC setup like the one we used for random forests raises the question of how to best integrate HANA with computing clusters, for instance, via SAP XS. This topic also needs further research; from a business perspective, a seamless integration of such external resources to train models might create a competitive advantage.

For some of these options, we have already performed tests with promising preliminary results, while others have raised additional questions that will be addressed in the context of a new research cooperation with OOWV. Also – and while highly desirable – an in-depth discussion of alternative modeling approaches (such as sustainability balanced scorecards) or better approaches for the estimation of joint probability distributions would go well beyond the scope of this (10-page) paper but might become the subject of further related research.

The versatility of the potential data sources in the approach described, in combination with the wide variety of KPIs, suggests that our approach may help detect and quantify causal relationships that have either not yet been considered in strategic sustainability management or have not been given this priority. In addition, many sustainability guidelines are influenced by national legislation or are often designed by companies or developed countries and hence vary in their importance for developing countries or across international borders. Therefore, the above approach could reveal unknown relationships and thus support sustainability goals at the international level.

This paper was written as part of a research collaboration with the OOWV. We would like to thank the OOWV for providing some of the technical infrastructure, data, and constructive feedback.

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Empowering Sustainability in Digital Education Leveraging SSI Wallets

Visman Jeet Singh Walia, Malte Rathjens, Ksenia Neumann, Damanpreet Singh Walia, Stefan Weidner & Prof. Dr. Klaus Turowski
Otto von Guericke University Magdeburg, Magdeburg, Germany

Abstract: Digital education is a crucial component of the modern learning landscape, yet it often lacks sustainability measures necessary to mitigate its environmental impact. This contribution proposes a novel approach to empowering sustainability in digital education by leveraging Self-Sovereign Identity (SSI) wallets. The integration of SSI wallets can enable a decentralized, user-centric model for managing digital identities, credentials, and educational records, reducing reliance on centralized data storage and fostering a more environmentally conscious digital education ecosystem. These concepts are crucial for future digital educational infrastructures, such as those being investigated within the Bildungsraum Digital (BIRD) Project. By harnessing the principles of self sovereignty and decentralization, this framework could have positive effects on environmental impacts associated with digital education while enhancing data privacy, security, and user control. Furthermore, the adoption of SSI wallets can streamline administrative processes, reduce paperwork, and facilitate seamless cross-institutional collaboration, ultimately driving sustainable innovation in the digital education sector. The research of this proposition will provide valuable insights for researchers, educators, and policymakers seeking to champion sustainability in the digital education.

Keywords: Digital education, Self Sovereign Identity, EUDI Wallet, BIRD Project, Sustainability

ESG meets EOG – Environment Social Governance strukturieren mit dem Enterprise Online Guide (EOG)

V. Bekiri[1]), E. Bayramli[3]), S. Stöckler[1]), H. Scheruhn[2]), & T. Bretschneider[2])
[1]) OST – Ostschweizer Fachhochschule, St. Gallen, Schweiz
[2]) Hochschule Harz, Wernigerode, Deutschland
[3]) msg systems ag, München, Deutschland

Abstract: In den letzten Jahren ist das Thema Nachhaltigkeit, unter anderem aufgrund von Regulierungen, aktueller Natur- und Energiekrisen immer mehr von einem Randthema zu einem Hauptthema geworden. Die Gestaltung von nachhaltigeren Produkten und Dienstleistungen hat deshalb für viele Unternehmen nun eine hohe Priorität. Um nun ein Unternehmen zielgerichtet bei der Einführung und Umsetzung des Nachhaltigkeitsmanagement zu unterstützen, wird die Systematik des Unternehmensarchitekturmanagements (EAM) am Beispiel Enterprise Online Guide (EOG) genutzt. Wesentliche Faktoren, die für das gesamte Unternehmen betrachtet werden müssen, sind in der CSRD und in ESG-Initiative definiert. Diese Themen sind nun in den EOG verankert. Im Enterprise Online Guide werden auch passende Modelle wie beispielsweise die Sustainability Balanced Score Card referenziert. Somit dient der EOG als Navigationswerkzeug für die holistische Nachhaltigkeitsplanung, um durch ein Unternehmen zu navigieren und alle angegebenen Strukturen zu definieren.

Keywords: Nachhaltigkeitsmanagement, Unternehmensarchitekturmanagement, Enterprise Online Guide, Corporate Social Responsibility, Environmental Social Governance

1. Einleitung

In den vergangenen Jahren ist das Thema Nachhaltigkeit (NH) mit den drei Säulen Ökologie, Gesellschaft und Ökonomie nicht zuletzt aufgrund der spürbaren Auswirkungen des Klimawandels zu einem immer bedeutenderen Treiber für Veränderungen in Unternehmen geworden. Während es zuvor eher als Randthema betrachtet wurde, hat sie sich aufgrund von Regulierungen, aktuellen Krisen wie Naturkatastrophen und Energiekrisen sowie einem gesteigerten Bewusstsein bei den Verbrauchern zu einem zentralen Anliegen entwickelt, das die meisten Unternehmen beschäftigt. (Hinrichs, 2023, S. 109–120)

Es ist daher keine Frage mehr, dass einerseits nachhaltiges Wirtschaften langfristig ein Schlüssel für erfolgreiche Geschäftsmodelle sein wird, und andererseits die Reporting-Vorschriften (CSRD oder vergleichbare, z.B. in der Schweiz) die Unternehmen vor vielfältige Aufgaben stellen. (vgl. z.B. (Erchinger, Koch & Schlemminger, 2022), (Bunzel & Friedemann, 2023), (Höring, 2023) oder (Hütter, 2022)).

Die Frage, wie die Nachhaltigkeitsbemühungen von Unternehmen im Rahmen des Prozessmanagements effektiv umgesetzt und gemessen werden können, steht im Mittelpunkt. Zur Beantwortung der Frage wird ein prozessorientiertes Rahmenwerk zur Strategiedefinition, kontrollierten Umsetzung sowie Kommunikation von NH-Ansätzen eingesetzt und dabei auch die Kriterien für die Bewertung und die Einbeziehung aller drei Dimensionen berücksichtigt.

1.1. Drei Dimensionen mit gegenseitigen Abhängigkeiten/Beeinflussungen

Die drei Dimensionen der Nachhaltigkeit – Ökonomie, Ökologie und Soziales - umfassen eine Vielzahl von Aspekten, die gleichzeitig als Bewertungskriterien dienen können. (Hinrichs, 2021, S. 34–35) Da sich diese ESG-Bereiche aber jeweils gegenseitig beeinflussen, können sie nicht isoliert optimiert werden, vielmehr bewegen wir uns in einem klassischen Spannungsdreieck.

Diese Themenblöcke und auch die generellen Zielsetzungen sind sowohl unter dem Begriff Corporate Social Responsibility (CSR) als auch unter Environmental, Social, Governance (ESG) bekannt. Der Begriff CSR ist, der Europäischen Kommission nach, definiert als die Integration von gesellschaftlichen, ökologischen, ethischen sowie Menschenrechts-Aspekten in die Geschäftstätigkeiten und Strategien. (Schneider & Schmidpeter, 2015, S. 25–37)

In diesem Dokument werden daher die beiden Abkürzungen synonym verwendet. Einerseits ist ESG schon weit verbreitet und andererseits hat CSR durch die Reporting-Richtlinie der EU-Kommission CSRD (Directive (EU) 2022/2464, 2022) neuerdings mehr Gewicht bekommen.

Nur wenn CSR- und ESG-Themen nicht als notwendige additive, parallele Aufgaben, sondern als integrale Bestandteile der Unternehmensführung etabliert sind, werden sie auch langfristig die gewünschten Auswirkungen zeigen. (Schneider & Schmidpeter, 2015, S. 25–37)

Die drei Dimensionen ökologische, soziale und ökonomische Nachhaltigkeit zusammen mit CSR auf Level 2.0 nach (Schneider, 2015, S. 33) und höher ergeben eine solide Zieldefinition für Unternehmen zur Einführung des Nachhaltigkeitsmanagement. (Schaltegger et al., S. 10)

1.2. Nachhaltigkeitsmanagement aufbauen und umsetzen

Damit Unternehmen grundsätzlich in ein langfristig erfolgreiches Nachhaltigkeitsmanagement kommen, müssen sie passende Methoden und Modelle aufbauen, die eine Operationalisierung ihrer Ziele erlauben. Gastinger & Gaggl (2015) zeigen in ihrem Beitrag, wie ein grundsätzlicher Weg für ESG von der Strategiedefinition über eine kontrollierte Umsetzung hin zur Kommunikation und zum Reporting aussehen kann. (Gastinger & Gaggl, 2015, S. 291)

Was bei diesem Weg von der Strategie zum Reporting jedoch fehlt, ist ein Rahmenwerk mit geeigneten Methoden und Modellen, um Ziele und Ergebnisse der Arbeitsschritte aus Abb. 1 zu strukturieren sowie umfassend und verständlich zu dokumentieren. Nur dann ist es möglich, die unternehmensglobalen NH-Ansätze auf untergeordnete Abhängigkeiten herunterzubrechen, sowie alle relevanten Aspekte eines Unternehmens von der Planung über Verantwortlichkeiten und Datenquellen bis zur Kommunikation zu berücksichtigen und in Einklang zu bringen.

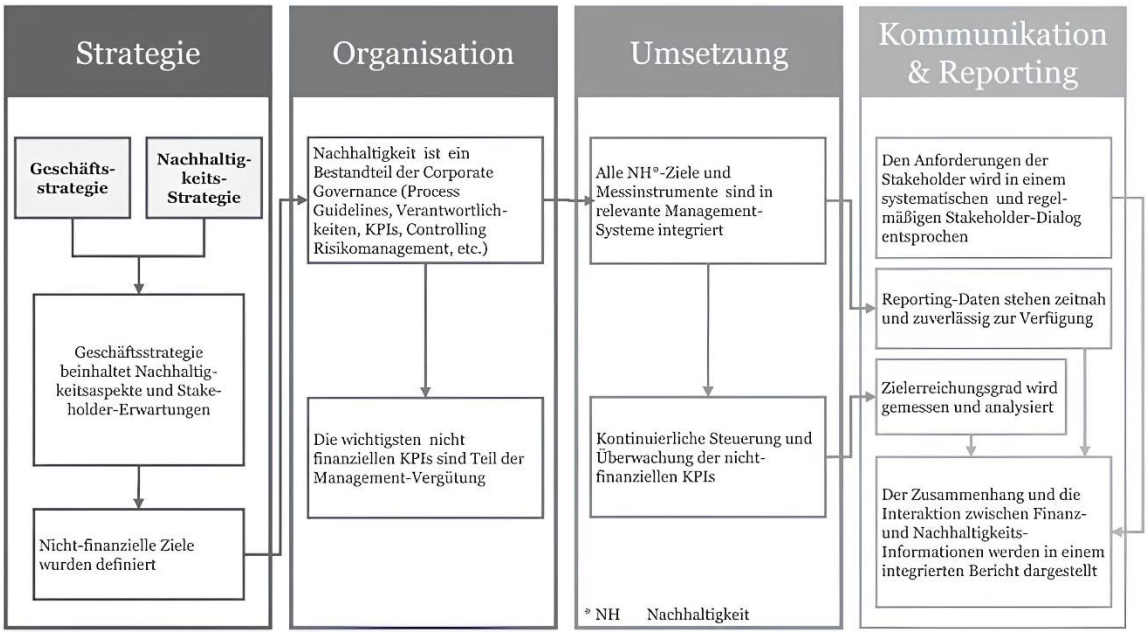

Abb. 1: Operationalisierung der NH-Ziele
(Quelle: (Gastinger & Gaggl, 2015, S. 291))

Eine Methode, um eine ESG-Strategie zu operationalisieren, sind die bekannten Balanced Scorecards (BSC) von Kaplan & Norton (1997). Eine Erweiterung zu Sustainablity BSC (SBSC) wurde von (Figge et al., 2002) vorgeschlagen und nach (Hansen, 2010) sind verschiedene Namensgebungen für die verschiedenen Perspektiven gerechtfertigt.

Um eine Brücke zwischen dieser und weiteren notwendigen Methoden und Modellen zur Operationalisierung von ESG zu schlagen, wird nachfolgend der Enterprise Online Guide (EOG) von (Scheruhn et al., 2023) als übergeordnetes Management-Tool vorgestellt.

2. Der Enterprise Online Guide – EOG

Der Enterprise Online Guide entstand über die Idee von Hans Scheruhn, Weidner & Müller (2024), ein Navigationsinstrument durch ein Unternehmen zu schaffen. Dabei stützt sich der EOG auch auf die bekannten Enterprise Architecture Frameworks nach TOGAF (vgl. z.B. The Open Group, 2022) und (Zachman, 1987).
Auf der Vertikalen werden die vier Abstraktionsebenen (Level) Corporate Management, Area Management, Workplace und Experience unterschieden, auf der Horizontalen finden sich acht unterschiedlichen Sichtweisen (Views) auf die betrachtete Organisation. In dieser Matrix entsteht eine konsequente Systematik mit unterschiedlichen Perspektiven, von denen in diesem Dokument die ersten sechs verwendet werden (vgl. (Scheruhn et al., 2024, S. 3)):

- **Motivation**. In dieser Sicht werden die Ziele festgelegt. Je nach Level sind das Unternehmens-, Abteilungs- oder Arbeitsplatzziele, die eine hierarchische Dekomposition darstellen.
- **Organization**. Hier wird die notwendige prozessorientierte Organisationsstruktur des Unternehmens aufgezeigt. Auf jeder Ebene werden die passenden Skills und Verantwortungen (Rollen) zugeordnet.
- **Function**. In dieser Perspektive werden im Wesentlichen die Business Capabilities beschreiben, die für die Leistungserbringung benötigt werden.

- **Process**. Die Prozess-Sicht ordnet dann die Abläufe und damit die Anwendung der Funktionen / Business Capabilities in zeitliche Abfolgen zur Erreichung der unternehmerischen Ziele.
- **Application**. Für die Ausführung der Prozessschritte werden meist IT-Anwendungen verwendet, die in dieser Perspektive zugeordnet werden.
- **Data**. Die letzte der Perspektiven widmet sich den Daten, die für die Ausführung der Prozesse und Funktionen benötigt werden bzw. währenddessen entstehen.

Die Sichten Technology und Network werden in diesem Dokument aufgrund des Umfanges nicht weiter beachtet.

Durch diese Systematik können nun passende Modelle für das klassische ökonomische Management zugeordnet werden. Dabei verwenden Scheruhn et al. sogenannte View/Level-Koordination. So bezeichnet z.B. M1 das Feld auf der Ebene Corporate Management in der Spalte Motivation, während O123 die Organisationsstrukturen übergreifend auf den Ebenen Corporate Management, Area Management und Workplace bezeichnet.

Vorschläge für Methoden und Modelle zur klassischen, ökonomischen Unternehmensführung, die in den unterschiedlichen Feldern verwendet werden können, sind ebenfalls in (Scheruhn et al., 2023) und (Scheruhn et al., 2024) angeführt.

Aufbauend auf dieser Idee des EOG als Orientierungshilfe, um durch ein Unternehmen zu navigieren, wird im folgenden Abschnitt gezeigt, wie damit auch ESG-Strategien bzw. CSR-Maßnahmen geplant, dokumentiert oder operationalisiert werden können.

3. EOG als Navigationswerkzeug für holistische Nachhaltigkeitsplanung

Aktuell entstehen unterschiedliche Werkzeuge für das Nachhaltigkeitsmanagement, vor allem im Bereich der Berichtserstellung nach CSRD, was jedoch fehlt sind konzise und praxisnahe Frameworks von der Kennzahlenentwicklung über die Datenbeschaffung bis hin zu einem kontinuierlichen Monitoring. (vgl. z.B. (Spahn) oder (Stork))

Salopp formuliert fehlen die Routen / die Landkarten (Maps) vom Startpunkt, der für die CSRD die doppelte Wesentlichkeitsanalyse ist, bis zu einem gesuchten Zielpunkt, der z.B. die Frage beantwortet, welche Datengrundlage in welchem System bzw. in welcher Datenbank zur Messung eines ESG-KPIs herangezogen werden kann. Und genau hier hilft nun der EOG, wenn man diesen, wie in der nachfolgenden Abb. 2 vorgeschlagen, um ESG-Artefakte erweitert.

	Sustainability Map				Intelligence Map	
	Motivation	Organization	Function	Process	Application	Data
1 Corporate Management	Double Materiality Assesment, Corporate ESG Goals, CSR Strategy	Corporate ESG Responisbilitiy, Chief Sustainabilty Officer (CS0)	Assignment of ESG activites to Business Capability (Business Capability Tree)	End-to-End-Processes (e.g. P2P, O2C,...) effecting CSR KPIs	IT Systems	ESG Data Lake
2 Area Management	ESG-Goals of External / Internal Stakeholders	ESG Responsibility: Organisational Unit	Assignment of ESG activites to Business Capability (Business Capability Tree)	Area Process (Across Departements) effecting CSR KPIs	IT System Landscape	ESG: Aggregated Data
3 Workplace	Worksplace ESG Objectives	ESG Responsibility: Role	Business Objects (e.g. Product or Customer) effecting CSR KPIs	Process Step effecting CSR KPIs	Task, Use Case, Event	Data Model Including ESG-Facts
4 Experience	CSR Key Performance Indicators (KPI)	Resources, Working Contract and Employee Experience	CSRD-Report	Process Performance Indicator (PPI) including CSR KPIs	CSR Measurement	Event- & Log-Data, Tables, Referential Integrity

Abb. 2: EOG mit ESG/CSR-relevanten Inhalten
(Quelle: (Eigene Darstellung))

Die CSRD fordert wie andere ESG-Initiativen zu Beginn eine doppelte Wesentlichkeitsanalyse. Diese wird im EOG im Feld M1 (Motivation / Level 1) verortet. Auf dieser Ebene werden auch die konzern- bzw. unternehmensweiten Zielgrößen und die dafür notwendigen ESG-Strategien definiert. Die Operationalisierung erfolgt in M1 mittels einer SBSC, wie in der nachfolgenden Abb. 3 dargestellt, welche zeigt, wie eine SBSC mit Fokus auf unternehmensweiten ESG- bzw. CSRS-Aspekten aufgebaut werden kann. Hier wird die ESG-Sicht (Environment, Social and Governance) noch explizit um die notwendige ökonomische Komponente ergänzt, wodurch sich vier Handlungsstränge ergeben.

Dadurch wird nun die Möglichkeit geschaffen, einen Top-Down-Ansatz einzuschlagen und über die EOG-Ebenen M2 (Area Management) und M3 (Workplace) die vorgegebenen Ziele auf die Organisationseinheiten herunterzubrechen.

Analog kann über die horizontale Verknüpfung in der Organization-Map (O123) die Verantwortlichkeit für die Zielerreichung zugeordnet werden. Darüber hinaus liefern Function (F) und Process (P) klare Zuweisungen zu Business Capabilities und Prozessschritten, die für die ESG-Maßnahmen relevant sind. Jeweils horizontal vernetzt mit der Motivation (M) und vertikal gegliedert im Top-Down-Ansatz.

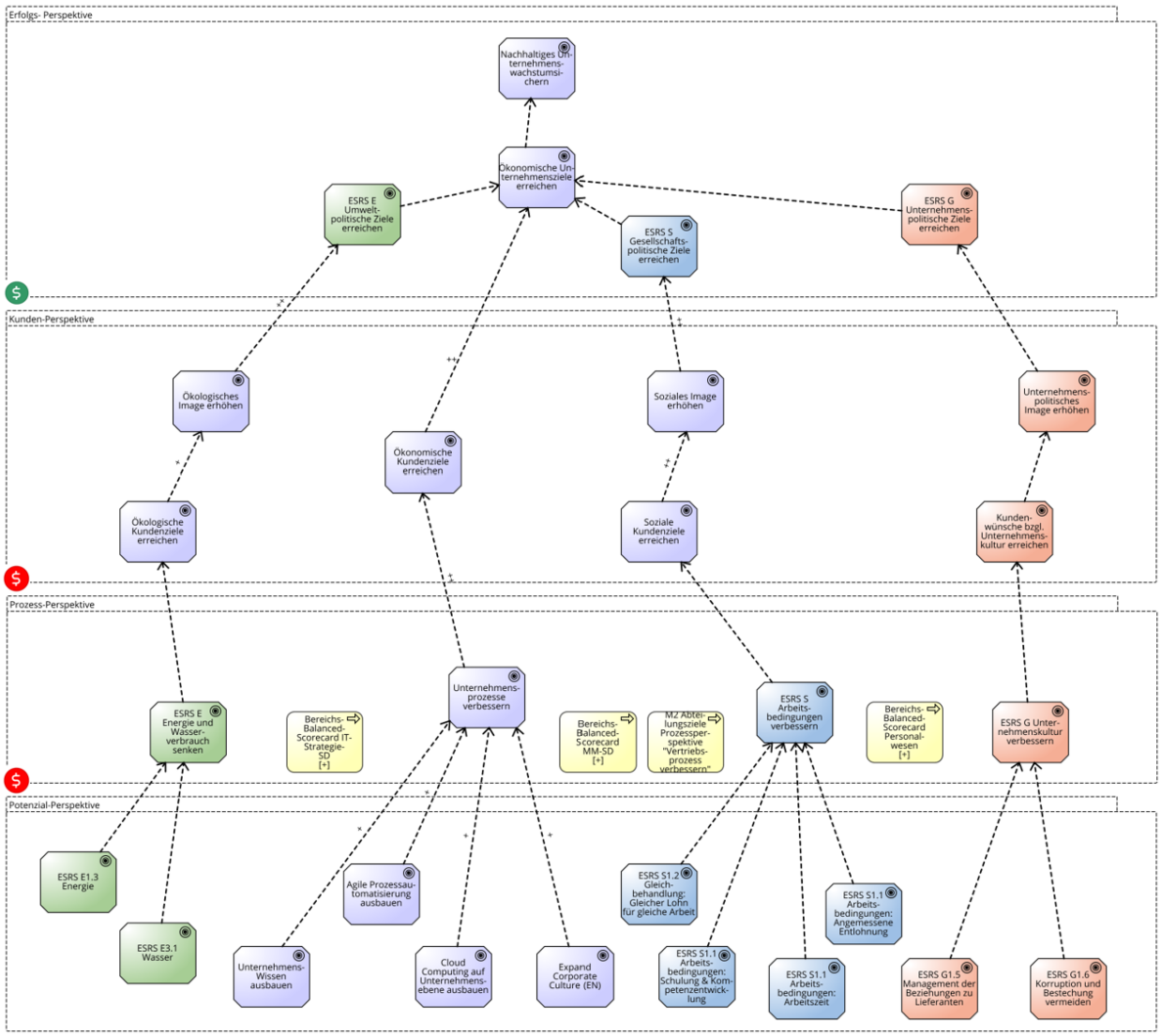

Abb. 3: Ausschnitt eines Beispiels einer SBSC mit ESRS-Vorgaben (Quelle: (Eigene Darstellung in Anlehnung an: (Scheruhn et al., 2024))

Der EOG unterstützt damit die Umsetzung des in Abb. 1 gezeigten Weges von der Strategieentwicklung bis zum Reporting (siehe Tab.1). Alle notwendigen Schritte können dadurch systematisch auf verschiedene Organisationsebenen und -funktionen verteilt werden und bei entsprechender Verknüpfung (Linking) ist eine durchgehende Nachverfolgbarkeit/Traceability von den Zieldefinitionen zu den Datenquellen und umgekehrt von den einzelnen Datensätzen zu den ESG-KPIs möglich.

Tab.1: Nachhaltigkeitsoperationalisierung mit dem EOG (Quelle: (Eigene Dartellung))

NH-Operationalisierungsschritt (Abb. 1)	EOG (Abb. 2)
Strategie	Definition der **M**otivation Map
Organisation	Definition der **O**rganization Map
Umsetzung	Definition der Maps: **F**unction, **P**rocess, **A**pplication, **D**ata
Kommunikation und Reporting	Nutzung des gesamten EOG als Grundlage für Wissenstransfer

Was im EOG implizit möglich ist und hier genutzt wird, ist die in Abschnitt 1.1 aufgezeigten drei, voneinander abhängigen Dimensionen (ökonomisch, ökologisch, sozial) direkt zu verknüpfen.

3.1. ESG meets EOG – Fallbeispiel nach SBSC

Als konkretes Beispiel wird im Folgenden die SBSC aus Abb. 3 noch einmal aufgenommen und den EOG-Feldern zugeordnet:

- In der unternehmensweiten SBSC der Motivation Map auf dem Level 1, Corporate Management (M1), werden Ziele zu den drei Dimensionen der Nachhaltigkeit (ESG) über alle vier BSC-Perspektiven verteilt dargestellt.
- In der Potential Perspective der unternehmensweiten SBSC werden unter anderem die für das Unternehmen relevanten ESRS-Themen genannt. Die Umsetzung dieser wird in der darüber liegenden Prozessperspektive spezifiziert. In Abb. 3 wurden die Potential- und die Prozessperspektive rot markiert. Diese Markierung dient als Frühwarnsystem, welches verdeutlichen soll, dass das Nichterreichen der Ziele aus der Potentialperspektive negative Auswirkungen auf das Erfüllen der Ziele in den weiteren BSC-Perspektiven haben kann.
- Darüber hinaus werden in der Kundenperspektive die Anforderungen und Erwartungen der Kunden hinsichtlich der Nachhaltigkeit identifiziert und in nachhaltige Produkte und Dienstleistungen umgesetzt, die den ESRS-Vorgaben entsprechen.
- Letztendlich werden in der Erfolgsperspektive die sozialen, ökonomischen und ökologischen Ziele festgelegt und zusammengeführt, welche den Erfolg des Unternehmens gemäß der Unternehmensstrategie gewährleisten.
- In der Motivation Map auf dem Level 2, Area Management (M2), werden Ziele für verschiedene Unternehmensbereiche wie dem Vertrieb oder der Materialwirtschaft in einer SBSC definiert, sowie die interne Kunden-Lieferanten Beziehungen zwischen zwei Unternehmensbereichen dargestellt. Hier werden die in M1 definierten Ziele auf die verschiedenen Unternehmensbereiche heruntergebrochen und damit deren Erreichbarkeit verifiziert.
- Zusätzlich sind auf dem Level 2, Area Management der Motivation Map (M2), die drei Nachhaltigkeitsdimensionen des ESG mit dem Prozess des jeweiligen Unternehmens-bereiches (P2) verknüpft, um zu verdeutlichen, wie Strategie und Prozess des jeweiligen Unternehmensbereiches zusammenarbeiten, um die Erfüllung der Nachhaltigkeitsziele auch auf der Bereichsebene eines Unternehmens zu gewährleisten.

Wie das Beispiel zeigt, führt der EOG systematisch durch die Hierarchie-Ebenen und kann zudem in einem nächsten Schritt die passenden IT-Applications (A*), Functions (F*) und Data (D*) zuordnen. Mit der Definition der Verantwortlichkeiten in der Organization-Map (O) kann das Bild dann vervollständigt werden.

In Abb. 4 sind einige wenige dieser Beziehungen anhand eines Fallbeispiels zu SAP visualisiert, allerdings lassen sich in einer solchen Graphik nicht alle Zusammenhänge übersichtlich darstellen. Die gesamte Vernetzung muss in einer entsprechenden Applikation abgebildet werden. Damit ist dann eine vollständige Navigation möglich, die auch das Generieren und

Aggregieren der Kennzahlen auf die verschiedenen Ebenen zulässt und die Messung der Zielerreichung unterstützt. Als Beispiel wird hier vereinfacht dargestellt, dass über das ESRS Thema E2-5 „Besorgniserregende Stoffe“ eine Reduktion von Giftstoffen in den Rohmaterialien angestrebt wird. Die Auswirkungen dieses Zieles sind in Abb. 4 am Beispiel der SmartFactory@OST als Musterunternehmen (Stöckler et al., 2021) aufgezeigt. Daher werden auch in den Perspektiven Application (A) und Data (D) die SAP-relevanten Begriffe verwendet:

- SAP Material Management (SAP MM) & Material Management – Purchase (MM-PUR) und die Transaktion MM02 für das Ändern von Materialstammdaten
- Sustainability Control Tower (Sus.Contr.Tower), SAP Analytics Cloud (SAP SAC), SAP Datasphere als Data Warehouse
- Tabelle MARA als Beispiel für den unternehmensweiten, zentrale Materialstamm

Darüber werden noch folgenden allgemeinen Abkürzungen in Abb. 4 verwendet: Enterprise to Enterprise (E2E), Process Performance Indicators (PPI) und Bill of Material (BOM)

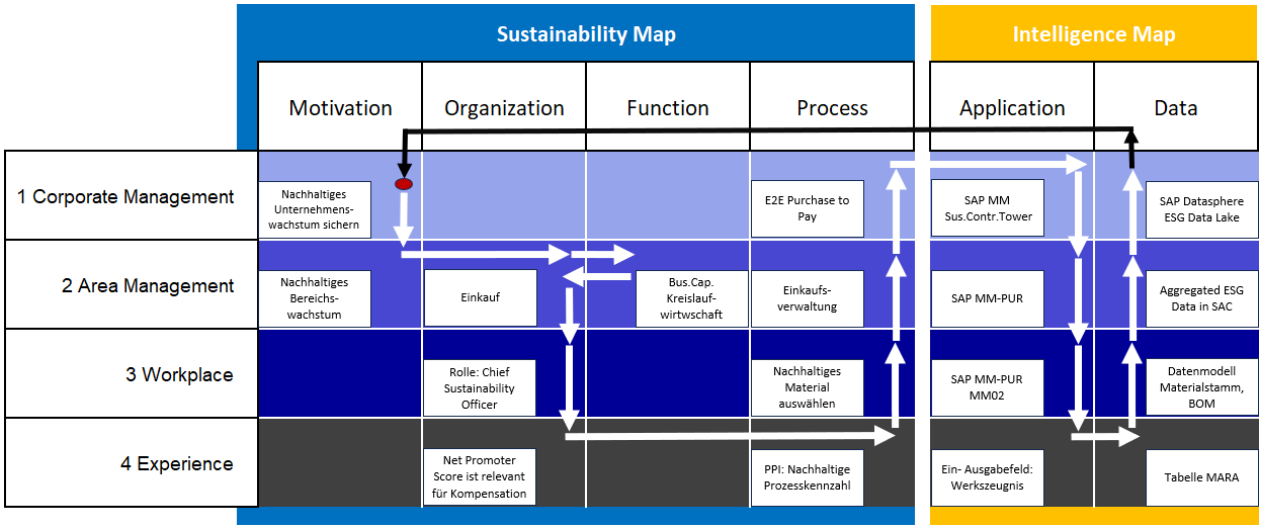

Abb. 4: ESG meets EOG – Fallbeispiel für SAP
(Quelle: (Eigene Darstellung))

Nach der Top-Down-Phase in der Planung wird dasselbe Netzwerk dieser Artefakte genutzt, um aus einzelnen Datensätzen (Stamm- und Bewegungsdaten) Bottom-Up die definierten ESG-KPIs zu errechnen und anschliessend im Reporting zu kommunizieren.

4. Zusammenfassung und Ausblick

In diesem Beitrag wurde gezeigt, wie der EOG als Rahmen für die Entwicklung, Durchführung und Steuerung von ESG-Maßnahmen genutzt werden kann. Die grundlegende Systematik des EOGs erlaubt eine integrative Sicht auf alle drei ESG-Dimensionen – Ökonomie, Ökologie und Soziales. Es sind keine Ergänzungen oder Veränderungen an der ursprünglichen Definition notwendig.

Der EOG bildet ein solides Framework für eine durchgängige Orientierung über ein gesamtes Unternehmen, wobei besonders die Verlinkung der einzelnen Elemente von der Strategie bis hinunter zu den Datenfeldern hervorgehoben werden muss. Dies ermöglicht eine langfristige Ausrichtung der gesamten Tätigkeiten mit einer klaren Führung über die Zieldefinitionen, die

ohne Beschränkung finanzieller oder ökologischer bzw. sozialer Natur sein können. Damit können in weiterer Folge Unternehmen den Nachhaltigkeitsaspekt tiefgreifend nach dem CSR-Reifegradmodell im Unternehmen verankern.

In nächsten Schritten ist geplant, ein Beratungs-Framework auf dem vollständigen EOG aufzubauen, dass die Begleitung von ESG-Projekten von der doppelten Wesentlichkeitsanalyse bis hin zur Operationalisierung der Datenerhebung, der KPI-Berechnung, des Reportings und ev. auch des Benchmarkings erlaubt. Aktuell werden auch die Sichten Technology und Network nicht beachtet. Diese Sichten werden in weiterer Folge über ergänzt werden.

Potenziell wäre die SmartFactory@OST als Beispiel aus der produzierenden Industrie dafür angedacht. Die SmartFactory@OST realisiert ein produzierendes Unternehmen für Lehrzwecke in der OST- Ostchweizer Fachhochschule. Eine kurze Beschreibung des Settings ist in (Stöckler et al., 2021) zu finden. Kurz umrissen handelt es sich bei der SmartFactory@OST um eine kunststoffverarbeitende virtuelle Firma, mit real existierenden Maschinen, Produkten und Prozessen. Daher eignet sich diese Umgebung auch als Fallbeispiel für ESG-Themen.

Grundidee in der SmartFactory@OST ist, im Sinne der Nachhaltigkeit möglichst auf Kreislaufwirtschaft zu setzen. Daher soll in allen Produkten künftig vermehrt bzw. nur noch Recycling-Material eingesetzt werden.

Durch die Systematik des EOGs lassen sich einerseits die vorhandenen Datenquellen identifizieren und mit den definierten Zielen verknüpfen und andererseits fehlende KPI-Grundlagen erkennen. Sind die datentechnischen Voraussetzungen gegeben, kann über den EOG und die dort verlinkten Elemente identifiziert werden, in welchen Prozessen die Merkmale zum Tragen kommen und wie diese erfasst oder automatisiert in die Transaktionsdaten gespeichert werden können. Damit kann der EOG auch im Bereich des ESG/Nachhaltigkeitsmanagements in der Lehre optimal eingesetzt werden.

Wie in einer realen Umsetzung müssen die softwaretechnischen Voraussetzungen erkannt und vorangetrieben werden. Anhand des eingesetzten SAP S/4HANA-Systems erlernen die Studierenden, wie die Integration von ESG-Massnahmen in die Systemwelt gelingen kann. Über den EOG werden die gesamten Zusammenhänge und die beiden Ansätze Top-Down und Bottom-Up in verständlicher Weise dargestellt. Darüber hinaus können eigene Beispiele anhand der EOG-Systematik entwickelt werden.

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Sustainable Product-Service-Systems

Bjørn Jæger[1], Terje Andersen[1], Agaraoli Aravazi[1] and Tom Ronny Olsson[2]
[1]Molde University College, Molde, Norway
[2]UiT The Arctic University of Norway, Narvik, Norway

Abstract: To achieve a more sustainable future, the circular economy is key. This requires a new product perspective with life phases in circles consisting of Beginning-of-Life (BoL), where parts converge into a product (manufacturing), Middle-of-Life (MoL), where the product is used, and End-of-Life (EoL), where the product ends its life, diverging into parts again. Circular strategies rely on Enterprise Systems needing Master Data to work. However, actors still have little knowledge of which Master Data are needed to support circularity or how these data can support decisions in circular manufacturing strategies. We present a framework bridging circular strategies with Master Data elements, and a case of an Oil & Gas Service Company with Sustainable Product-Service-Systems needs. Finally, we compare these needs with our current teaching of the SAP Customer Service (CS) module at two universities in Norway.

Umweltfreundliche Bildungsnachweise: Systementwurf und Erfahrungen mit elektronischen Kurszertifikaten

T. Kiertscher, R. U. Franz
Technische Hochschule Brandenburg, Deutschland

Abstract: Wenn Studierende an Online-Kursen einer Hochschule teilnehmen, erhalten sie nach Bestehen oft ein Kurszertifikat, welches Kursinhalt, Umfang in ECTS und Note ausweist.

Die gewohnte Praxis, Kurszertifikate handschriftlich zu unterschreiben und postalisch zu versenden, wird bei sehr vielen Kursteilnehmern zu aufwändig; insbesondere, wenn die Kurse weltweit angeboten werden. Ein elektronisches Kurszertifikat kann den zeitlichen, materiellen und finanziellen Aufwand für die Hochschule deutlich reduzieren und zusätzlich Mehrwerte schaffen. Eine langfristig verfügbare Echtheitsprüfung spiegelt dabei den Wert des Kursabschlusses wider.

Um die Erstellung und Verifikation der Kurszertifikate optimal in die Verwaltung der Online-Kurse integrieren zu können, wurde ein eigenes System entwickelt, welches die Digitalisierungsstrategie der Hochschule innovativ unterstützt und durch Prozessoptimierungen deutlich nachhaltiger arbeitet. In diesem Beitrag wird der Systementwurf vorgestellt und einige wichtige Entwurfsentscheidungen erläutert. Ein Rückblick auf drei Jahre im Betrieb erlauben die Bewertung des Systems hinsichtlich Aufwandseinsparung.

Keywords: Online-Lehre, Kurszertifikat, Nachhaltigkeit, Digitale Prozesse

1. Einführung

In der heutigen Bildungslandschaft stehen Studierende vor dem anspruchsvollen Ziel ihre akademische Ausbildung abzuschließen und möglichst gut für den späteren Berufseinstieg vorbereitet zu sein. Um dieses Ziel zu erreichen, bietet unsere Hochschule Online-Kurse an, die sowohl akademische Inhalte vermitteln, aber gleichzeitig auch auf die Berater-Zertifikatsprüfungen der SAP vorbereiten. Die Zertifikate der SAP sind praxisnah aber die vom Unternehmen zur Vorbereitung ausgegebenen Schulungsunterlagen sind nicht akademisch aufgebaut, sondern zielen inhaltlich direkt auf die Prüfungen. Sie bieten den Studierenden eine Dokumentation praxisrelevanter Kenntnisse, die sich eng an den Anforderungen der Wirtschaft orientiert und sind damit besonders wertvoll für Studierende, die sich auf eine Karriere in der Wirtschaft vorbereiten. Allerdings werden sie in vielen Hochschulen nicht anerkannt, da sie keine Note enthalten, der Arbeitsumfang nicht ersichtlich ist und sie nicht auf wissenschaftlichen Grundlagen basieren.

Im Gegensatz dazu werden Hochschulzertifikate von akkreditierten Hochschulen vergeben, enthalten eine Note, dokumentieren akademische Inhalte und sind in der Regel mit der Anrechnung von ECTS-Leistungspunkten verbunden. Dies macht sie nicht nur in der akademischen Welt anerkannt, sondern ermöglichen auch die Anrechnung im Rahmen von Studienprogrammen.

Alle von unserer Hochschule angebotenen Online-Kurse im Themengebiet *Enterprise Ressource Planning* (ERP) schließen bei erfolgreichem Bearbeiten und Bestehen mit einem

Hochschulzertifikat ab. Auf Wunsch können die Studierenden im Anschluss an der Prüfung für das zugehörige SAP-Zertifikat teilnehmen. Da es sehr hohe Teilnehmerzahlen bei diesen Online-Kursen mit Studierenden aus aller Welt gibt, war der Aufbau eines Online-Zertifikatssystems notwendig.

2. Stand der Technik

Zertifikate von Hochschulen wurden in der Vergangenheit üblicherweise in Papierform mit einem Siegel und handschriftlichen Unterschriften ausgegeben. Dabei weist das Siegel nach, dass die Urkunde tatsächlich von der Hochschule stammt, indem der physische Zugriff auf das Siegel durch geeignete Maßnahmen auf einen bestimmten Personenkreis beschränkt ist. Die Unterschriften erhöhen die Fälschungssicherheit durch ihre individuelle Linienführung. Die Fälschungssicherheit einer Unterschrift, besonders wenn diese in einer großen Zahl von Urkunden verbreitet wird, ist zwar weiterhin anerkannt, jedoch nicht unanfechtbar (Yeung et. al., 2004).

Wenn ein bisher in Papierform erstelltes Zertifikat in eine elektronische Form überführt wird, z. B. in das *Portable Document Format* (PDF), gehen Merkmale an Siegel und Unterschrift verloren, die von einem Experten genutzt werden können, um die Echtheit zu überprüfen. Siegel und Unterschrift werden in einem PDF auf eine Pixel- oder Vektorgrafik mit begrenzter Auflösung reduziert. Diese lässt nicht nur viele Details vermissen. Sie kann auch verlustfrei kopiert und in anderen Dokumenten wiederverwendet werden.

Elektronische Dokumente sind ohne weiteres nicht vor Manipulationen geschützt. Der Inhalt von PDF-Dateien lässt sich mit einer großen Auswahl an Programmen beliebig verändern. Die Integrität, die ein Blatt Papier bietet, indem es die einmal aufgedruckten und handschriftlich geschriebenen Inhalte zu einer Einheit verbindet, ist bei einer PDF-Datei nicht gegeben.

Um die Echtheit von digitalen Dokumenten sicherzustellen, haben sich die folgenden drei Verfahren etabliert: Elektronische Unterschrift, Digitale Signatur und Verifikations-URL.

Die **elektronische Unterschrift** ist nicht mehr als das Erfassen einer handschriftlichen Unterschrift mit einem digitalen Eingabegerät wie Maus oder Touch-Pad als Vektorgrafik. Diese wird dann als grafisches Element in die PDF-Datei eingefügt. Nicht nur verändert das digitale Eingabegerät die Linienführung der Unterschrift zum Teil erheblich, die erzeugte Vektorgrafik bildet, mit der ursprünglichen PDF-Datei keine untrennbare Einheit. Deshalb kann der übrige Inhalt der PDF-Datei verändert werden, ohne die Unterschrift zu berühren.

Aufgrund seines geringen Aufwandes und dem aktuellen Rechtsrahmen findet diese schwache Methode eines Authentizitätsnachweises dennoch häufig Anwendung und wird auch von Softwareherstellern als sinnvolle Praxis propagiert. Darunter z. B. Adobe, das Unternehmen welches das PDF entwickelt hat, mit der *E-Signatur*[10] oder Stefan Ziegler als Teil der *PDF24 Tools*[11].

Die **digitale Signatur** ist eine informationstechnische Lösung, welche eine mathematische Prüfsumme über die Daten des Dokuments bildet und diese mit Hilfe von asymmetrischer Kryptografie verschlüsselt. Dadurch entsteht eine digitale Unterschrift, die an das Dokument

[10] https://www.adobe.com/de/sign/electronic-signatures.html
[11] https://tools.pdf24.org/de/pdf-unterschreiben

angefügt wird (Bertsch, 2002; Pelzl & Paar, 2016). Für das asymmetrische Verschlüsseln und den Identitätsnachweis des Unterzeichners ist ein digitales Zertifikat erforderlich. Das Vertrauen in ein digitales Zertifikat wird durch eine *Public Key Infrastructure* (PKI) hergestellt. Digitale Signaturen sind eine sichere Methode des Authentizitätsnachweises, solange die genutzten kryptografischen Algorithmen nicht angreifbar werden, die Algorithmen korrekt implementiert wurden und die privaten Schlüssel der Vertrauensstellen und des Unterzeichners geheim gehalten werden. Da eine PKI mit technischem Aufwand verbunden ist, sind digitale Zertifikate für den Unterzeichner i. d. R. nicht kostenfrei. Der PDF-Standard umfasst digitale Signaturen und viele Anbieter, u. a. Adobe[12], bieten diese als Dienstleistung an. Die Verwendung von digitalen Signaturen ist in der EU durch die eIDAS-Verordnung geregelt (eIDAS VO (EU) 910/2014). Das *Deutsche Forschungsnetz* (DFN) stellt eine PKI für digitale Signaturen zur Verfügung (Gröper, 2022).

Bei der **Verifikations-URL** wird in das Dokument eine URL als Hyperlink oder als Text eingefügt, welche den Aufruf einer Webseite auf einem Verifikationsserver erlaubt. Diese zeigt dann i. d. R. jene Informationen an, die unverfälscht im Zertifikat stehen sollten. Ein Abgleich der Informationen aus dem Dokument mit denen auf der Webseite offenbart zuverlässig Manipulationen am Dokument. Der Verifikationsserver muss dafür die wesentlichen Informationen von allen ausgegebenen Dokumenten vorhalten. Ein Beispiel für eine etablierte Nutzung dieser Technik, sind die Kurszertifikate der Online-Lern-Plattform Coursera[13], welche u. a. den Namen des Lernenden, den Kursnamen, die Unterschrift der Lehrkraft als Grafik (s. *Elektronische Unterschrift*) und die Verifikations-URL enthalten.

3. Anforderungen

An ein System zur Ausstellung und Verifikation von Kurszertifikaten an unserer Hochschule werden die folgenden Anforderungen gestellt. **Betriebssicherheit:** Mit der Betriebssicherheit ist hier vornehmlich die Resilienz gegen illegale Zugriffe über das Internet, aber auch aus dem Intranet der Hochschule gemeint. Die Sicherheit muss langfristig gewährleistet werden. **Fälschungssicherheit:** Es muss mit erheblichem Aufwand verbunden oder theoretisch unmöglich sein, gefälschte Zertifikate auszustellen, oder manipulierte Zertifikate unter Anwendung der Verifikationsmöglichkeiten als echt erscheinen zu lassen. **Erweiterbarkeit:** Das System muss an eine zunehmend digitalisierte Infrastruktur angepasst und in teilautomatisierte Arbeitsabläufe integriert werden können. Ein für die Hochschule quelloffenes System ist dabei sehr hilfreich. **Abhängigkeiten:** Das System soll weitgehend unabhängig von externen Dienstleistern und auch unabhängig von den Dienstleistungen des DFN betrieben werden können. Das System soll auch unabhängig vom zentralen *Hochschulinformationssystem* (HIS) der Hochschule betrieben werden können, da die Verwaltung der Online-Kurse in einem spezialisierten System erfolgt. **Funktionalität:** Authentifizierung von Unterzeichnern am System mit dem zentralen Hochschul-Account; Verifikation ausgedruckter Zertifikate; Zertifikate in mehreren Sprachen; Verwaltung für grafische Vorlagen; Online-Editor für das Platzieren und Formatieren von Freitext und Datenfeldern; Import der Datensätze über ein verbreitetes Datenformat (z. B. CSV); Korrektur und Widerruf von ausgestellten Zertifikaten. **Rechtlicher Rahmen:** Das System muss den

[12] https://www.adobe.com/de/sign/digital-signatures.html
[13] https://www.coursera.support/s/article/208280196-Course-Certificates

aktuell geltenden rechtlichen Bestimmungen, insbesondere der DSGVO entsprechen (DSGVO (EU) 2016/679).

4. Systementwurf

In diesem Abschnitt wird der Entwurf des Zertifikatssystems beschrieben. Zunächst wird kurz die Wahl der Authentifizierungsmethode begründet. Dann wird die grobe Architektur vorgestellt, und das Konzept für die Integritätssicherung der Zertifikatsdaten erläutert. Nach einer Beschreibung des Ablaufs zur Verifikation eines ausgestellten Zertifikats, werden einige technologische Entscheidungen erläutert.

4.1. Authentifizierungsmethode

Eine grundlegende Entscheidung, die im Entwicklungsprozess getroffen wurde, ist die Authentifizierungsmethode für die Zertifikate. Die elektronische Unterschrift wurde als ungenügend bewertet, um die Anforderung der Fälschungssicherheit zu erfüllen. Die digitale Signatur würde Abhängigkeiten zu externen Dienstleistern mit sich bringen, die vermieden werden sollen. Übrig bleibt das Konzept der Verifikations-URL.

4.2. Architektur

Das System ist in zwei Komponenten gegliedert: Den *Manager* und den *Verifikator*. Beide haben eine eigene Datenbank. Der Manager stellt eine Verwaltungsoberfläche im Intranet der Hochschule bereit. Er speichert Zertifikatsvorlagen und Zertifikatsdatensätze in einer Datenbank und ermöglicht den Versand von ausgestellten Zertifikaten über den E-Mail-Server der Hochschule. Beim Ausstellen eines Zertifikats schreibt der Manager einen verschlüsselten Verifikationsdatensatz in die Datenbank des Verifikators. Der Verifikator hat nur lesenden Zugriff auf seine Datenbank. Die Komponenten und ihre Nutzer sind in Abb. 1 dargestellt.

Die Trennung des Systems in Manager und Verifikator hat einige Vorteile im Vergleich mit einem monolithischen System:

- Die Angriffsfläche aus dem Internet wird minimiert. Angriffe auf den öffentlich erreichbaren Server treffen zunächst nur den Verifikator.
- Der Verifikator besitzt nur sehr wenig Funktionalität, was seine Komplexität verringert und so weiter die Angriffsfläche minimiert.
- Gelingt einem Angreifer aus dem Internet der Einbruch in den Verifikator, erlangt er nur lesenden Zugriff auf verschlüsselte Datensätze.
- Verwaltungsfunktionen und Mechanismen zur Integritätssicherung der Datenbank des Managers können unabhängig vom Verifikator aktualisiert werden.
- Der Manager kann bei Wartung oder, langfristig gedacht, auch bei Stilllegung des Systems abgeschaltet werden, ohne die Funktionalität des Verifikators zu beeinträchtigen.

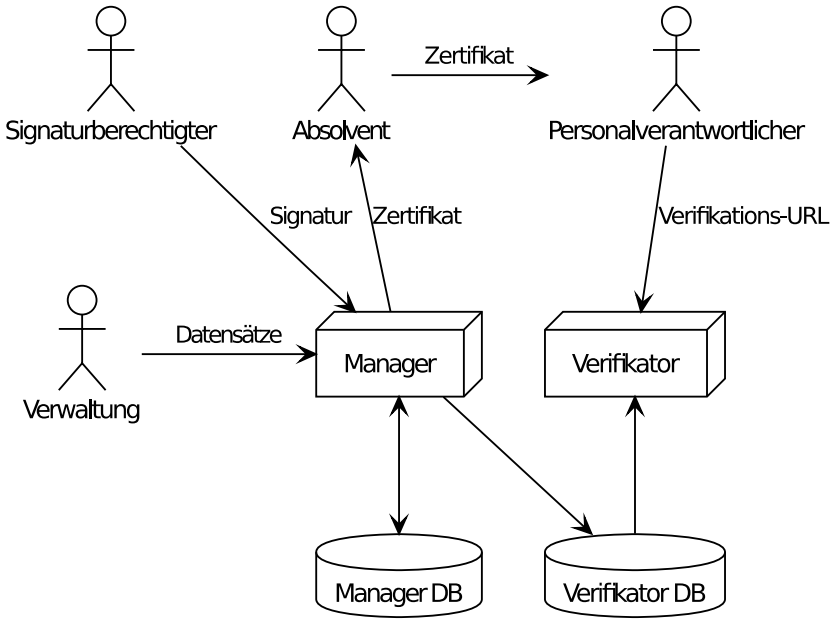

Abb. 1: Systemübersicht

4.3. Integritätssicherung

Die Integritätssicherung der Zertifikatsdatensätze soll langfristig sicherstellen, dass die zugrunde liegenden Daten von ausgestellten Zertifikaten nicht nachträglich in der Datenbank des Managers manipuliert werden können. Die Maßnahmen zur Integritätssicherung sind für den Fall vorgesehen, dass ein Angreifer schreibenden Zugriff auf die Datenbank des Managers erlangt hat.

Als Sicherungsmaßnahme wird eine Kette von digitalen Signaturen verwendet. Der Unterzeichner verwendet dabei ein selbst-signiertes digitales Zertifikat, welches nicht durch eine PKI, sondern durch ein starkes Passwort gesichert ist. Die Manipulation eines einzelnen Datensatzes oder das böswillige Hinzufügen eines Datensatzes könnte auch ohne eine Kette aufgedeckt werden. Sie dient jedoch dem Zweck, dass auch das Löschen von Datensätzen nachweisbar wird. Wird ein Angriff aufgedeckt, muss die Datenbank aus einer Sicherungskopie wiederhergestellt werden.

4.4. Zertifikatsausstellung und Widerruf

Das System sieht vier Rollen für Benutzer vor: Administrator, Sachbearbeiter, Signaturberechtigter und Prüfer. Ein **Administrator** weist anderen Benutzern die übrigen Rollen im Zertifikatssystem zu. Ein **Sachbearbeiter** legt Zertifikatsvorlagen an, importiert Datensätze, ordnet Zertifikatsvorlagen zu und stellt *Signaturanfragen* für einen oder mehrere Datensätze.

Ein **Signaturberechtigter** legt sich ein Siegel an (selbst-signiertes digitales Zertifikat); und prüft und bewilligt Signaturanfragen. Das System sieht neben Signaturanfragen auch Widerrufs- und Korrekturanfragen vor. Wird eine Widerrufsanfrage bewilligt, legt das System einen signierten Widerrufsdatensatz an, der den Zertifikatsdatensatz des widerrufenen Zertifikats referenziert. Eine Korrektur erzeugt einen Widerrufsdatensatz gefolgt von einem neuen Zertifikatsdatensatz.

Ein **Prüfer** hat lesenden Zugriff auf Datensätze, Zertifikatsdatensätze und Widerrufsdatensätze und hat die Möglichkeit einen Integritätsprüflauf auszulösen.

Durch die Trennung der Rollen Sachbearbeiter und Signaturberechtigter, kann das System das Vier-Augen-Prinzip effektiv umsetzen; welches optional durch die Rolle des Prüfers um eine dritte Partei erweitert werden kann.

Wird ein Zertifikatsdatensatz in der Datenbank des Managers angelegt, wird eine zufällige aber in der Datenbank eindeutige ID und ein zufälliger symmetrischer Schlüssel als Teil des Zertifikatsdatensatzes erzeugt. Aus der ID, dem Schlüssel und der Internetadresse des Verifikationsservers, kann später die Verifikations-URL gebildet werden. Anschließend wird in der Datenbank des Verifikators unter Verwendung von ID und Schlüssel ein verschlüsselter Verifikationsdatensatz angelegt. Wird ein Widerrufsdatensatz in der Datenbank des Managers angelegt, wird der referenzierte Verifikationsdatensatz gelöscht. Die Datenbank des Verifikators kann jederzeit, mit Hilfe der Kette von Zertifikats- und Widerrufsdatensätzen aus der Datenbank des Managers, auf Integrität überprüft und auch vollständig wiederhergestellt werden.

4.5. Verifikationsablauf

Der Verifikator stellt eine einfache Webseite im Internet bereit, auf welche die Verifikations-URL verweist. Sie zeigt bei einem gültigen Zertifikat den zugehörigen Datensatz an. Dazu extrahiert der Verifikator den Verifikations-Code aus der URL und ruft mit der ID den Verifikationsdatensatz ab. Er entschlüsselt diesen mit dem Schlüssel und zeigt die enthaltenen Informationen an. Die Webseite des Verifikators kennt nur zwei Anzeigezustände:

- *Der Verifikations-Code ist ungültig:* Entweder wurde kein verschlüsselter Datensatz für die ID gefunden, oder der Versuch der Entschlüsselung mit dem Schlüssel aus dem Code war nicht erfolgreich.
- *Der Verifikations-Code ist gültig:* Der Datensatz wird angezeigt und der Benutzer muss die Informationen zwischen Webseite und Zertifikat vergleichen, um festzustellen, ob das Zertifikat unverändert und damit echt ist.

4.6. Technologische Entscheidungen

Zur Implementierung wurden die folgenden Technologien gewählt: Java und JavaScript (Programmiersprachen), Spring Boot (Application Framework), MySQL (Datenbank), Bouncy Castle (Programmierbibliothek für Kryptografie), Apache PDFbox (Programmierbibliothek für PDF-Erstellung und Manipulation), RSA-Signaturen. Auswahlkriterien waren dabei hauptsächlich Verbreitung und langfristige Verfügbarkeit von Sicherheits-Updates.

Der Verifikations-Code soll möglichst leicht fehlerfrei abzuschreiben sein. Der Code ist an die *Bubble-Babble*-Kodierung angelehnt und besteht aus fünf 5er-Gruppen (Huima, 2011). Das verwendete Alphabet und die erlaubten Wechsel von Konsonanten und Vokalen weichen vom Standard ab, um die Kapazität zu erhöhen; verzichtet dabei aber auf die Prüfsummenfunktion. Die ID nimmt die ersten zwei Gruppen ein (Entropie ≈ 41 Bits). Das erlaubt bis zu 2,2E+12 Zertifikate auf einem Verifikationsserver. Bei einer Hochschule mit 10 000 ausgestellten Zertifikaten/Jahr und einer Betriebszeit über 100 Jahren, werden lediglich 0,000 05% des verfügbaren ID-Raumes genutzt. Der Schlüssel nimmt die übrigen drei Gruppen ein (Entropie ≈ 61 Bits).

Ein Verifikations-Code könnte wie folgt aussehen: „abeci-dofug-omnip-sefgo-ijaku“

Eine Zertifikatsvorlage besteht aus einer PDF-Datei als grafischer Hintergrund, Freitext- und Datenfeldern, dem Hyperlink für die Verifikations-URL und optional einem *QR-Code*[14].

Um den Ressourcenbedarf zu minimieren, werden Zertifikate dynamisch beim Versenden aus Zertifikatsvorlage und -datensatz generiert und nicht als Datei auf dem Server gespeichert.

5. Evaluierung

Das primäre Ziel der Einführung der elektronischen Kurszertifikate war die Reduzierung des Aufwands. Tab. 1 stellt ihn nach Papiermenge, Kosten und Zeit dar. Bei den Portokosten wurden Einsparungen bereits dadurch erlangt, dass Sammelsendungen an ausländische Partneruniversitäten geschickt wurden. Der Aufwand für die Systementwicklung belief sich auf 4 Monate Vollzeit für einen akademischen Mitarbeiter mit abgeschlossenem Informatikstudium.

Tab. 1: Aufwände

Form	Material/Kostenart	Ø Papier/Jahr	Ø Kosten/Jahr	Rolle	Ø Zeit/Jahr
Papier	Versandtaschen	240 kg	401 €	Unterzeichner	40 h
	Zertifikate/Druck	50 kg	704 €	Verwaltung	200 h
	Porto		3 015 €		
	Summe	**290 kg**	**4 120 €**		**240 h**
Elektr.	Material	0 kg	0 €	Unterzeichner	5 h
	Betrieb		150 €	Verwaltung	15 h
				Entwickler	10 h
	Summe	**0 kg**	**150 €**		**30 h**

Für den Betrieb wird eine VM mit 2 CPUs, 3 GB RAM und 32 GB SSD-Speicher benötigt. Die Kosten dafür sind auf 150€/Jahr geschätzt. Eine vergleichbare VM als Amazon AWS EC2, kostet zum Zeitpunkt der Drucklegung 0,04$/h und damit 320€/Jahr, oder 185€/Jahr über drei Jahre.

Mit dem Zertifikatsystem wurden bisher 21 647 Zertifikate ausgestellt und versendet. In Tab. 2 sind die ausgestellten korrigierten und widerrufenen Zertifikate je Semester gelistet. Tab. 3 enthält die Verzögerungen, mit der Widerrufe oder Korrekturen durchgeführt wurden. Eine Analyse des Zugriffsprotokolls des Verifikators über 4 Monate hat die Statistik in Tab. 4 ergeben.

Tab. 2: Zertifikate nach Semestern

Semester	ausgestellt	korrigiert	widerrufen
SS 2020	3107	5	2
WS 2020/21	3144	36	2
SS 2021	2625	16	1
WS 2021/22	2199	6	0
SS 2022	2137	1	4
WS 2022/23	2064	5	0
SS 2023	1819	6	0
WS 2023/24	2161	13	0

[14] https://www.denso-wave.com/en/technology/vol1.html

Tab. 3: Korrekturen und Widerrufe

Verzögerung	Anteil
gleicher Tag	3
gleiche Woche	48
gleicher Monat	27
gleiches Halbjahr	11
gleiches Jahr	2
später	1

Tab. 4: Anfragen an den Verifikator in 4 Monaten

Ergebnis	Anfragen	Kommentar
Gültig	16 015	ID bekannt, nicht widerrufen, Schlüssel OK
Nicht gefunden	1	ID unbekannt
Widerrufen	21	ID bekannt, widerrufen
Ungültig	1	ID bekannt, Schlüssel ungültig
Exploits	1 006	Nicht vorgesehene URL-Parameter
Summe	**17 042**	

6. Zusammenfassung

Die Entwicklung und Einführung eines Systems für die Ausstellung von elektronischen Zertifikaten für Online-Kurse hat in unserer Hochschule für eine deutliche Reduzierung von monetärem und zeitlichem Aufwand geführt und spart eine große Menge an Papier ein. Der wegfallende internationale Versand ist deutlich nachhaltiger. Das System bietet eine hohe Betriebssicherheit und benötigt auch bei langfristigem Betrieb wenige Ressourcen.

Zukünftig ist die direkte Anbindung an die Online-Kursverwaltung mit automatischem Transfer der Datensätze für Kursabschlüsse und eine Modernisierung der Integritätssicherungsmaßnahmen durch den Wechsel von RSA auf ED25519 geplant.

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SAP ERP: Ihr Schlüssel zur Nachhaltigen Unternehmensführung

Christian Palzenberger, Felix Wöss
SAP Österreich GmbH

Abstract: SAP hat eine umfassende Nachhaltigkeitsstrategie entwickelt, um Unternehmen bei der Erreichung ökologischer, sozialer und ökonomischer Ziele zu unterstützen. Der USP von SAP liegt in der Integration von Nachhaltigkeitsmetriken in ihre Softwarelösungen (ERP-zentrierter Ansatz), die Echtzeit-Daten für nachhaltige Entscheidungen bieten. Kontinuierliche Innovation bei SAP Nachhaltigkeitslösungen ermöglicht es Unternehmen ihre gesteckten Ziele in Hinblick auf Erreichung von Netto-Null-Emissionen, Förderung von Kreislaufwirtschaftsmodellen und Stärkung sozialer Verantwortung zu unterstützen. Initiativen wie "SAP Green Ledger", welche in Zukunft eine gemeinsame Bilanzierung von Finanz- und Nachhaltigkeitskennzahlen ermöglichen, und transparente Lieferketten (CSDDD) sind zentrale Bestandteile dieser Vision.

Keywords: Sustainability, SAP Green Ledger, Carbon Footprint, Reporting, CSRD

CSRD, Lieferkettengesetz der EU, EU Entwaldungsverordnung: Auswirkungen auf Unternehmen und möglicher IT Support

Dominik Ladich, Thomas Grasser
KPMG

Abstract: Supply Chain Management ist schon seit vielen Jahren ein wichtiges Thema für Unternehmen, durch das neue Lieferkettengesetz aber auch die CSRD und ESRS kommen neue Anforderungen auf Unternehmen zu. Ein wichtiger Punkt ist der CO^2 Abdruck, der durch Lieferungen von Materialien und Services in die CSRD Berichterstattung auf zu nehmen ist. Wie kann dies durch ERP Systeme unterstützt werden und wie können die neuen Prozesse in Unternehmen aussehen? Weiters werden die ersten Ansätze für ein Curriculum in diesem Bereich dargestellt.

WORKSHOP 1: INTERNATIONALISIERUNG

Workshop Organisation: Jorge Marx Gomez, Andreas Solsbach, Barbara Rapp Michael Mattern

Integrating Big Data Analytics with Enterprise Resource Planning for Sustainable Business Practices

Imani Omboto
NM-AIST, Arusha, Tanzania

Abstract: This paper investigates the integration of Big Data Analytics (BDA) with SAP Enterprise Resource Planning (ERP) systems and its impact on sustainability-related Key Performance Indicators (KPIs). By examining existing literature, the study highlights how the combination of BDA and SAP ERP systems enhances resource utilization, improves inventory management efficiency, and reduces energy consumption. The findings indicate that organizations leveraging these integrated systems achieve substantial reductions in material waste and operational costs, thereby boosting overall sustainability performance. Additionally, the paper underscores the significance of SAP's sustainability tools, such as SAP Sustainability Footprint Management, which utilizes Machine Learning and Big Data to facilitate accurate carbon emissions tracking and strategic decision-making. This research emphasizes the transformative potential of BDA-SAP ERP integration in promoting sustainable business practices, offering valuable insights for organizations aiming to enhance their environmental footprint and operational efficiency.

Keywords: Big Data Analytics, Enterprise Resource Planning, Sustainability, SAP Enterprise Resource Planning Systems, Key Performance Indicators (KPIs)

1. Introduction

In today's business landscape, sustainability has become a strategic imperative driven by regulatory demands and market expectations (Elkington, 2018). The integration of Big Data Analytics (BDA) with Enterprise Resource Planning (ERP) systems presents a promising approach to achieving sustainability goals. ERP systems enhance operational efficiency and resource management, while BDA provides critical insights through advanced data analysis (Sweeney, 2018; Davenport, 2014). Recent studies indicate that integrating BDA with ERP systems can significantly improve demand forecasting, inventory management, and waste reduction, thus promoting sustainable practices (Kiron, 2012). Furthermore, this synergy enhances the accuracy of sustainability reporting and compliance with environmental regulations, offering a strategic advantage in an eco-conscious market (Wamba, 2015). BDA's ability to process large volumes of data in real-time enables ERP systems to quickly adapt to changing market conditions and environmental requirements, which is crucial for implementing sustainable practices aligned with dynamic regulatory standards and consumer expectations (Raut, 2019). By leveraging predictive analytics, companies can optimize resource usage and reduce their environmental footprint, contributing to broader corporate sustainability and social responsibility goals (Jeble, 2018).

2. Literature Review

2.1. Enterprise Resource Planning Systems

ERP systems are designed to integrate various business processes, enhancing operational efficiency and resource management through real-time data access (Edward Sweeney, 2018). Modern ERP systems incorporate AI and machine learning for predictive maintenance, intelligent automation, and improved decision-making (Sehrawat, 2023). These advancements enable organizations to streamline operations, foresee potential disruptions, and reduce maintenance costs (Ucar, 2024). Additionally, cloud computing integration with ERP systems offers scalability, flexibility, and cost-efficiency, enhancing data security and compliance with global standards (Elmonem, 2016; Bitkowska, 2024).

2.2. Big Data Analytics

BDA involves analyzing vast datasets to uncover insights that inform business decisions (Chen, 2012). Recent technological advancements in data storage, processing, and visualization have made BDA critical for modern businesses (Wamba, 2015). Techniques like machine learning and natural language processing help extract valuable information from unstructured data, enhancing analytical capabilities essential for trend identification and operational optimization (McAfee, 2021; Borza, 2019). The integration of BDA with IoT devices further expands its applications, providing real-time insights into operational efficiencies and customer behaviors (Lee, 2015; Gharlbvand, 2024).

2.3. Sustainability in Business

Sustainable business practices aim to meet current needs without compromising future generations' abilities to meet theirs, encompassing environmental, social, and economic dimensions (Brundtland, 1987; Geissdoerfer, 2017). Companies are increasingly recognizing that sustainability enhances corporate reputation and drives long-term profitability (Kramer, 2011). Implementing sustainable supply chain practices reduces costs, improves resource efficiency, and mitigates environmental risks (Govindan, 2014). Stakeholders now place greater emphasis on sustainability performance, and companies addressing these issues are more likely to attract talent, secure investments, and build customer loyalty (Eccles, 2014).

2.4. Integrating BDA with ERP for Sustainability

The integration of BDA with ERP systems can drive sustainability by optimizing resource utilization, reducing waste, and improving decision-making processes (Sarkis, 2021). Real-time data analytics from BDA can provide insights into energy consumption patterns, enabling companies to implement energy-saving measures and reduce their carbon footprint (Mittal, 2019). Predictive analytics can help forecast demand and optimize inventory levels, minimizing waste and improving resource efficiency (Fathima, 2024). Moreover, BDA-ERP integration can enhance transparency and accountability in sustainability reporting, facilitating compliance with regulatory requirements and improving stakeholder trust (Zrnic, 2020; Alavi, 2023).

3. Methodology

This literature review synthesizes findings from existing research to explore the integration of Big Data Analytics (BDA) with Enterprise Resource Planning (ERP) systems for sustainability.

3.1. Data Collection

Data was sourced from academic journals, industry reports, and case studies published between 2019 and 2024. This review included metrics on resource utilization, waste reduction, and overall sustainability performance from a diverse range of companies that have implemented BDA and ERP systems (Wamba, 2015; Xu, 2018). Additionally, insights were gathered from secondary sources such as industry reports and academic articles to provide a comprehensive overview of the current state of BDA-ERP integration in various sectors.

3.2. Data Analysis

Quantitative data from the literature was analyzed to identify trends and correlations between BDA-ERP integration and sustainability outcomes. Key performance indicators (KPIs) related to resource optimization, waste reduction, and sustainability performance were examined (Field, 2018). The findings were visualized using charts and graphs to facilitate interpretation and communication (Wamba, 2015).

Qualitative insights from reviewed studies were thematically analyzed to uncover key themes and patterns. This process involved systematically reviewing the literature and identifying common themes regarding the benefits and challenges of integrating BDA with ERP systems for sustainability (Braun, 2016). The thematic analysis ensured that qualitative insights complemented the quantitative data, providing a robust and comprehensive understanding of the research problem.

4. Results and Discussion

4.1. Quantitative Findings

The integration of Big Data Analytics (BDA) with Enterprise Resource Planning (ERP) systems has been shown to significantly enhance sustainability-related Key Performance Indicators (KPIs). Studies have revealed that big data analytics capabilities have a significant influence on sustainable performance (Alyahya, 2023). This study also indicated that BDA analytics have a significant influence on enhancing the strategic agility of the company. This in turn leads to a significant influence on sustainable performance (Alyahya, 2023). The findings of this research do indicate that organizations with strong analytics capabilities -which are enhanced by BDA- are better positioned to achieve sustainable outcomes across various performance dimensions (Alyahya, 2023).

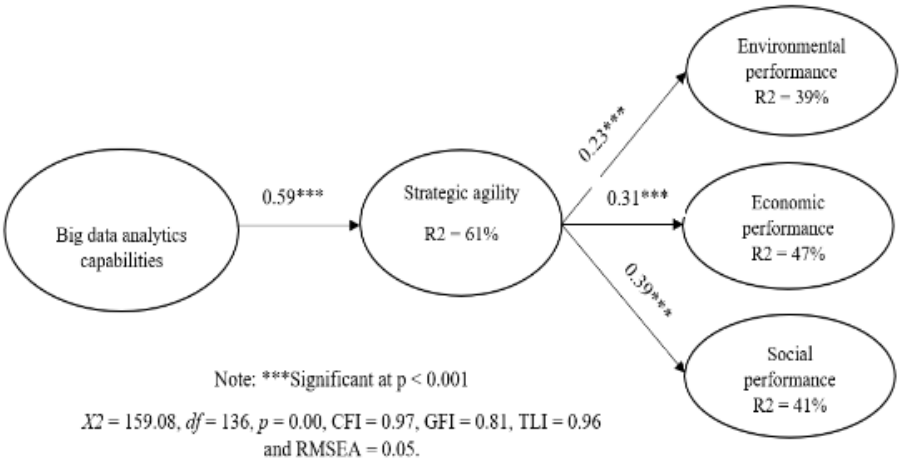

Fig. 1: (Alyahya, 2023).

This study found a significant relationship between BDA capabilities and firm creativity, economic performance, and even social performance as seen in Fig. 1, thus solidifying the notion that BDA integration is an important determinant affecting long-term performance of a company which in turn dispels the thought that only a company's tangible resources can assure its long-term performance (Alyahya, 2023).

Hypothesis	Relation	Standard Beta	*t* value	*p* value
H1	IF → SCS	0.544	9.64	0.000
H2	MC → SCS	0.467	7.75	0.008
H3	PC → SCS	0.514	8.57	0.002

Note: IF: infrastructure flexibility, MC: management capabilities, PC: personnel capability, SCS: supply chain sustainability.

Fig. 2: (Alzboun, 2023).

Studies also revealed that the components of big data analytics capability, including infrastructure flexibility, management capabilities, and personnel capabilities, had a positive effect on supply chain sustainability as seen in Fig. 2, which agrees with Zhu (2022) this is from Alzboun (2023). Companies may enhance inventory management and demand forecasting by making decisions based on big data analysis, resulting in reduced waste, improved productivity, and lower environmental consequences (Alzboun, 2023).

SAP, a global leader in enterprise applications and business AI, realized this truth way earlier, as early as 2008 when Daniel Schmid and Peter Graf presented their idea for a global sustainability project (Seidel, 2014). This global project resulted in vigorous research with 100 leading companies and institutions to create a sustainable future through software solutions offered by SAP (Seidel, 2014). Accolades are fitting for SAP in this initiative as the results did not just focus outward but also inward as by March 2009 SAP formed a sustainability council which governed all the sustainability related efforts (Seidel, 2014).

By designing more robust and environmentally conscious ERPs SAP managed to take and anchor a leading role in sustainability whereby its sustainability efforts managed to receive positive feedback from both employees and external stakeholders (Seidel, 2014). Figure 3 below shows the development of important KPIs (these sustainability KPIs were also defined by the SAP project) from the SAP integrated Report of 2012 which reveal a steady drop in

Environmental impact brought about by the SAP ERP systems being more finely tuned towards sustainability.

Table 3: Development of important KPIs (SAP Integrated Report 2012)							
Dimension	**KPI**	**2008**	**2009**	**2010**	**2011**	**2012**	**Change in %**
Environmental	Greenhouse gas emissions	560	480	455	490	485	-13,39
	Total energy consumption	N/A	860	845	860	860	00 (from 2009 to 2012)
	Data center energy	3146	3001	2746	2824	2598	-17,42
Social	Employee retention	92	94	93	93	94	+2,17
	Total female managers	18,1	17,6	17,8	18,7	19,4	+7,18
	Employee engagement	n.a.	69	68	77	79	+ 14,49 (from 2009-2012)
Economic	Software and software-related service revenue (IRFS)	8466	8198	9794	11319	13165	+ 55,5
	Operating margin in %	23	24	21	34	25	+ 8,7

Fig. 3: (Seidel, 2014).

This further emphasizes that ERPs made with sustainability in mind lead to sustainable business practices, as shown above, and also reveals why SAP has been ahead of its competitors, mainly due to the fact that it adopted the sustainability mindset earlier. Times have changed drastically since 2008 because, as of 2023, SAP invested heavily into developing Carbon accounting software; carbon accounting represents a process whereby an organization measures the amount of CO_2 (equivalents) it emits through its activities (SAP, 2024).

Through development of AI-powered software such as SAP Sustainability Footprint Management which utilizes Machine Learning and Big Data to enhance its analytical capabilities and it also integrates with other SAP Solutions such as SAP S/4HANA and SAP S/4HANA cloud to collect and analyze vast amounts of data (SAP, 2024), Companies are now able to actually track their carbon footprint and not just mere guess it; a good example of this is the Matsumoto Precision Inc, a Japanese company renowned for processing precision machine parts which has implemented SAP Sustainability Footprint Management to provide its business partners with detailed information on the CO_2 associated with each product they manufacture (SAP APJ, 2024). The integration of this software alongside SAP S/4HANA has improved productivity by approximately 30% and has also increased the speed of management decision-making (SAP APJ, 2024). This finely tuned approach would not have been achieved without integrating Big Data Analytics into the SAP ERP since Matsumoto Precision Inc can now visualize information on CO_2 emissions per product to its business partners (SAP APJ, 2024). The article further posits the idea that a recent study of the IDC (August 2023) found that one-third of the respondents identified carbon emissions monitoring software as one of the most efficient tools in enabling an organization's business objectives (SAP APJ, 2024).

4.2. Implications for Practice

The integration of Big Data Analytics (BDA) with SAP Enterprise Resource Planning (ERP) systems presents substantial opportunities for enhancing sustainability within organizations. The empirical evidence suggests that leveraging BDA within SAP's advanced analytics

capabilities can significantly reduce material waste, improve resource utilization, and enhance overall operational efficiency (Alyahya, 2023; Sheu, 2014). For practitioners, this means prioritizing the adoption of integrated BDA and SAP ERP solutions to achieve measurable sustainability outcomes. Implementing these technologies allows businesses to optimize their supply chains, minimize environmental impacts, and increase productivity by utilizing data-driven decision-making frameworks (Alzboun, 2023). Furthermore, the strategic use of SAP's sustainability tools, such as SAP Sustainability Footprint Management, can provide organizations with detailed insights into their carbon footprints, enabling them to track and reduce CO2 emissions effectively (SAP, 2024).

Companies must also focus on continuous improvement and stakeholder engagement to realize the full potential of BDA-SAP ERP integration. Regular assessment and enhancement of these integrated systems are crucial for maintaining alignment with evolving sustainability goals and technological advancements. Engaging stakeholders at all levels, from employees to external partners, ensures buy-in and collaboration, which are essential for the successful implementation and adoption of sustainable practices (Martinez, 2023). By fostering a culture that values sustainability and data-driven decision-making, organizations can enhance their strategic agility, economic performance, and social responsibility, ultimately driving long-term sustainable development (SAP APJ, 2024; Alyahya, 2023).

5. Conclusion

The integration of Big Data Analytics (BDA) with SAP Enterprise Resource Planning (ERP) systems represents a significant advancement in promoting sustainable business practices. The evidence presented in this paper underscores the positive impact of BDA-SAP ERP integration on sustainability-related Key Performance Indicators (KPIs), such as resource utilization, inventory management, and energy consumption. Organizations that leverage the sophisticated data analytics capabilities of SAP ERP systems can achieve substantial reductions in material waste and operational costs, enhancing their overall efficiency and environmental footprint (Alyahya, 2023; SAP, 2024). The findings affirm that companies with robust analytics capabilities are better positioned to achieve sustainable outcomes, thereby reinforcing the critical role of BDA in driving sustainable performance.

Furthermore, the strategic use of SAP's sustainability tools, such as SAP Sustainability Footprint Management, highlights the potential of integrating advanced technologies like Machine Learning and Big Data in sustainability efforts. These tools enable organizations to accurately track and manage their carbon emissions, thus supporting more informed and strategic decision-making (SAP, 2024). The empirical data and case studies discussed provide a compelling argument for businesses to invest in BDA-SAP ERP integration as a means to not only enhance their sustainability metrics but also to achieve long-term competitive advantages. Future research should continue to explore the evolving landscape of BDA-ERP integration, focusing on emerging technologies and their potential to further revolutionize sustainable business practices (Zamani, 2023; Wang, 2016).

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Monitoring Corporate ESG Performance: A Practice for Data-Driven Decision Making to Sustain Competitive Edge

E. Mkoba
Nelson Mandela African Institution of Science and Technology, Arusha, Tanzania

Abstract: In recent years, there has been a significant shift in the way corporates including government, public and private sector, report their environmental, social, and governance (ESG) performance to stakeholders. ESG reporting has become a critical tool for businesses worldwide, reflecting a growing awareness of the interrelation between corporate success and societal well-being. In an effort to increase productivity, efficiency, and business value, organizations are increasingly prioritizing sustainability in their corporate strategy goals. Nevertheless, in order to support data-driven decision making with emerging technologies, monitoring of ESG performance is still poorly explored. The study aimed to investigate how to monitor corporate ESG performance using emerging technologies. The methodology used is a desk review of literature from various databases, such as IEEE Xplore, Science Direct, Google Scholar, ACM, Scopus, and grey literature. The study proposed a framework that can be used to monitor corporate ESG performance. The framework comprises identifying key performance indicators, ESG metrics, ESG data, data analytics, ESG audits, financial reports, decision-making, ESG performance reports, and continuous improvement of ESG performance. The framework can be used by practitioners in the government, public, and private sectors to monitor ESG performance.

Keywords: Data Analytics, Environmental, Social, Governance, Sustainability

1. Introduction

Sustainability is becoming a more essential strategy for most organizations aimed at creating an impact on society and the environment. Recently, environmental, social, and governance (ESG) management practices in organizations have been changing rapidly to ensure sustainable socio-economic development (Seo et al., 2022; Truant et al., 2023; Li, 2024). The relevance of sustainability reporting has increased as more organizations realize how important it is to report on their ESG performance to stakeholders. Emerging technologies such as big data analytics and artificial intelligence (AI) are used for sustainability reporting, including automating the gathering and processing of ESG data, seeing trends and patterns in the data, and giving real-time insights into sustainability performance (Ahmad et al., 2023). An increasing number of investors are giving priority to businesses that emphasize sustainability, social responsibility, and ethical practices. The ability of organizations to gather, examine, and comprehend enormous volumes of information on their environmental, social, and governance policies is made possible by big data analytics, which is crucial to ESG performance (Nisar et al., 2020; Daying & Zi'Ao, 2023). ESG performance is focused on how resources are utilized and how their usage affects the environment and communities. Through the mitigation of resource imbalances, the digital transformation improves the ESG performance of corporations (Li et al., 2024).

However, in the literature, monitoring corporate ESG performance is still poorly explored, and a framework for monitoring ESG performance is lacking. In addition, standards for ESG

reporting could not provide a framework for monitoring corporate ESG performance. This study aims to investigate how to monitor corporate ESG performance for timely decision making.

The rest of this paper is organized as follows: Section 2 provides a literature review. The research methodology is presented in Section 3. The results are provided in Section 4. The discussion is presented in section 5. Finally, the conclusion and recommendations for future research are made in Section 6.

2. Literature Review

2.1. ESG Context

ESG reporting has growing importance because investors and other stakeholders require corporations to disclose more information about their sustainability activities and environmental, social, and governance strategies (Chen, 2022). The environmental, social, and governance (ESG) setting is a dynamic arena where regulatory, corporate, risk management, financial, and social demands are all taken into account when making decisions. Investors, analysts, and other stakeholders assess firms using ESG criteria, which take into account not just their financial performance but also their corporate social responsibility and sustainability. The environmental (E) evaluates how a company performs by considering its impact on climate change, resource depletion, pollution, waste management, and environmental risks. Social (S) assesses how a company manages relationships with its employees, suppliers, customers, and the communities where it operates. This includes factors such as labor practices, health and safety standards, diversity and inclusion, human rights, product safety, and community engagement. Governance (G) includes internal controls, policies, and structures that guide corporate behavior and decision-making. It includes aspects such as board independence, executive compensation, shareholder rights, transparency, ethical business practices, and compliance with laws and regulations. Corporate ESG reporting has a number of standards, as discussed in the next section.

2.2. ESG Reporting Standards

ESG reporting standards refer to guidelines that companies use to disclose their performance and impacts in these areas. These standards are important for transparency, accountability, and comparability among businesses and investors interested in ESG considerations. Table 1 shows some key ESG reporting standards that are widely recognized and used globally.

Tab. 1: Global ESG Reporting Standards

S/No.	Standard	Purpose	References
1	**Global Reporting Initiative (GRI)**	It provides a comprehensive set of standards and guidelines for companies to report their economic, environmental, and social impacts. This is a commonly used standard by corporates.	GRI (2022)
2	**Sustainability Accounting Standards Board**	It provides industry-specific standards for ESG topics that are material to financial performance. These standards help companies disclose financially material	SASB (2022)

S/No.	Standard	Purpose	References
		sustainability information to investors.	
3	**Task Force on Climate-related Financial Disclosures**	It focuses on helping companies disclose information about the risks and opportunities posed by climate change.	TCFD (2017)
4	**Carbon Disclosure Project**	It runs a global disclosure system for investors, companies, cities, states, and regions to manage their environmental impacts. It collects self-reported environmental data from companies and cities globally.	Cpd (2024)
5	**International Integrated Reporting Council**	It promotes integrated reporting, which connects sustainability and financial performance in a single report. It encourages companies to communicate how they create value over time.	Ifrs (2021)
6	European Sustainability Reporting Standards	They provide information for investors to understand the sustainability impact of the companies in which they invest.	Efrag (2023)
7	UN Global Compact (UNGC)	It provides principles for businesses to align their strategies and operations with universal principles on human rights, labor, environment, and anti-corruption. Companies are encouraged to report on their progress towards these principles.	**Fehler! Linkreferenz ungültig.**

These standards vary in their focus, scope, and applicability across different industries and regions. However, they all aim to provide a structured approach for companies to disclose relevant ESG information to stakeholders, including investors, customers, employees, and the broader community. Adhering to these standards helps corporations demonstrate their commitment to sustainable and responsible business practices while enhancing transparency and trust among stakeholders. Corporate adhering to these standards enhances the credibility of ESG data. Strengthening ESG performance requires collaboration between governments, businesses, investors, and civil society to address environmental, social, and governance issues effectively while driving sustainable development.

3. Methodology

The desk review was used as a research method to identify, assess, and synthesize related works relevant to the objective of this study. The study reviewed the existing literature that was published in peer-reviewed journals and conference papers from 2020 to June 2024 and the grey literature. The data sources were from digital library databases, namely, IEEE Xplore, Science Direct, Google Scholar, MDPI, ACM, Scopus, and various reports from the websites.

4. Results

The conceptual framework for monitoring corporate ESG performance is shown in Fig.1. The components of this framework were derived from the literature review as discussed below.

4.1. Component 1: Identify KPIs from ESG Goals

The fact that corporate strategy and ESG are integrated shows that ESG considerations are now a key component of business strategy development (Henderson & Van den Steen, 2021). Sustainability and social responsibility are becoming recognized as ways for businesses to reduce risks and increase long-term profitability. This means integrating ESG factors into strategic decision-making to ensure alignment with broader organization business goals. Organizations should develop an ESG strategy based on their corporate strategy and reporting standards. As illustrated in Figure 1, the first component of the framework involves the identification of the key performance indicators (KPIs) from the ESG goals.

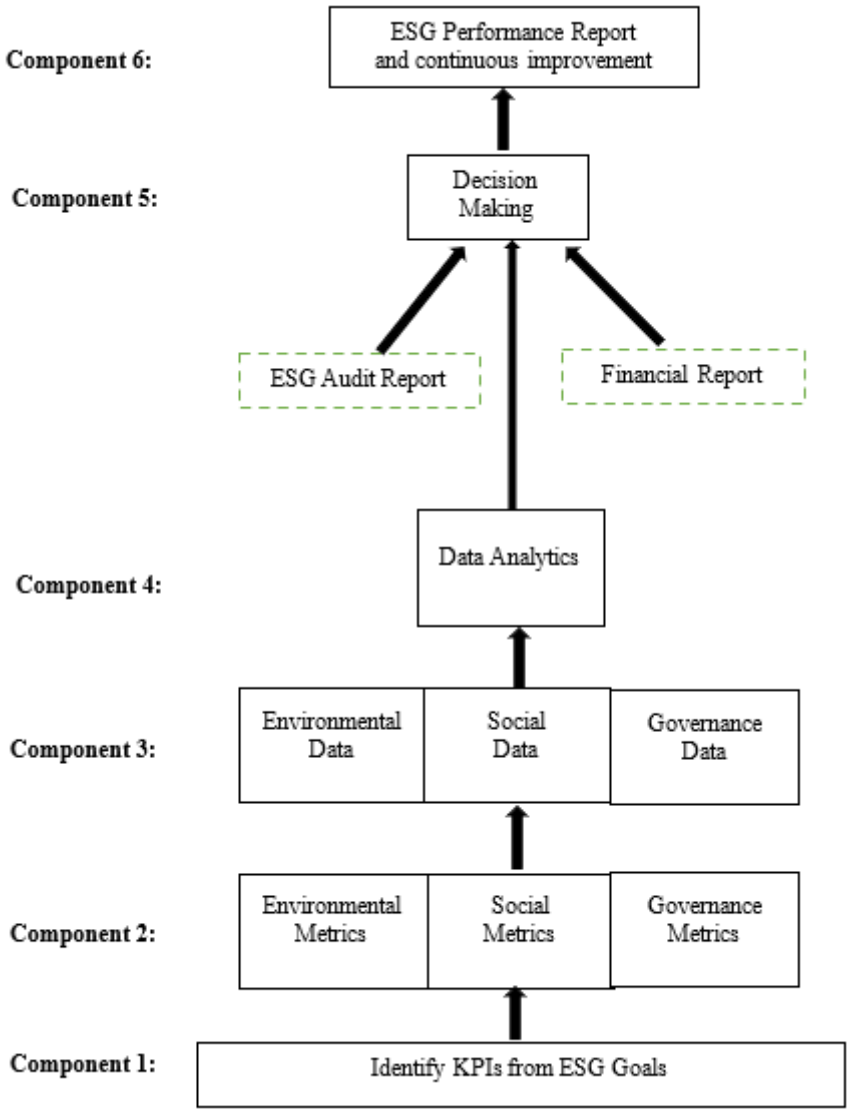

Fig. 1: Conceptual Framework for Monitoring Corporate ESG Performance

4.2. Component 2: ESG Metrics for corporate ESG performance

This study identified metrics for measuring corporate ESG performance. These metrics are divided into three categories, namely, environmental, social, and governance (Asif et al., 2023; Liu et al., 2023; Jina et al., 2023; Liu et al., 2024; Sariyer et al., 2024). Environmental metrics include greenhouse gas emissions, energy consumption, waste management, water usage, biodiversity, the company's environmental regulations and compliance approach. Social factors metrics are labor practices, diversity and inclusion, human rights, community engagement, health and safety, product safety, and social contributions. Governance metrics are corporate governance (board composition and compensation), risk management, investor relations, shareholder rights, conflict of interest (COI) policy, ethical business practice, compliance with regulations and policies, transparency, accountability, efficiency and effectiveness (achievement of organization's strategic objectives, impact assessments, and stakeholder satisfaction feedback through surveys). They are used as key performance indicators (KPIs) to evaluate the performance of ESG in organizations.

4.3. Component 3: ESG Data

ESG data helps enhance sustainability practices in business, which has different ESG standards for reporting (Truant et al., 2023). ESG data provides companies with a comprehensive understanding of their environmental impact, social responsibility, and governance practices. By collecting and analyzing ESG data, organizations can identify areas of improvement and implement strategies to enhance their sustainability performance. These data allow organizations to set meaningful targets, measure progress, and communicate their sustainability efforts to stakeholders. ESG data helps organizations align their operations with the United Nations Sustainable Development Goals (SDGs) for sustainable development. The types of ESG data that can be used by big data analytics for decision making are:

Environmental Data: The organization's efforts to mitigate climate change, minimize resource consumption, and safeguard natural ecosystems are the main topics of the environmental component of ESG data. These data are collected using environmental metrics such as greenhouse gas emissions, energy consumption, waste management, water usage, biodiversity, the company's environmental regulations and compliance approach.

Social Data: It examines how an enterprise impacts society, considering its interactions with clients, vendors, employees, and local communities. The social data are collected using social metrics as labor practices, diversity and inclusion, human rights, community engagement, health and safety, product safety, and social contributions.

Governance Data: The primary focus is on the guidelines, policies, and practices that govern how an organization makes decisions. The governance data are collected using governance metrics corporate governance (board composition and compensation), risk management, investor relations, shareholder rights, conflict of interest (COI) policy, ethical business practice, compliance with regulations and policies, transparency, accountability, efficiency and effectiveness (achievement of organisation's strategic objectives, impact assessments, and stakeholder satisfaction feedback through surveys).

4.4. Component 4: Data Analytics

As shown in Figure 1, ESG data evaluates a company's sustainability practices, ethical standards, and overall impact on society and the environment. Data analytics involves

examining ESG data using a number of techniques, such as machine learning algorithms, statistical analysis, data mining, and visualization, to extract meaningful information (Lee et al., 2022). These meaningful insights are used for decision making. According to Wang (2023) and Cheng (2024) digital strategy can enhance corporate ESG performance by applying big data analytics and AI to enhance decision making. The application of emerging technologies is essential in improving ESG performance, decreasing carbon footprints, emphasizing resource management, and supporting ethical corporate practices (Mouakket & Aboelmaged, 2022; Junjun et al., 2024).

4.5. Component 5: Decision Making

Environment, social, and governance (ESG) are influencing organizational decision-making processes. As shown in Figure 1, decision making using results from ESG data analytics and the ESG audit report is essential for organizations seeking to navigate complex global challenges, enhance stakeholder value, and achieve sustainable growth. By integrating ESG metrics into strategic and operational decisions, organizations can foster innovation, mitigate risks, build trust with stakeholders, and create long-term value for society and shareholders alike.

4.6. Component 6: ESG Performance Report and Continuous Improvement

After decision making, ESG performance reporting is essential. The performance report is aligned with the ESG reporting standards, ESG goals and target and will be published. A regular ESG performance assessment is required that will identify areas for improvement and develop a plan for continuous improvement of ESG performance.

5. Discussion

Other aspects to be considered in monitoring corporate ESG performance are data governance, cybersecurity, data privacy and protection, as well as stakeholders' engagement. ESG data governance faces several challenges that organizations need to address to effectively manage and utilize ESG information for decision making. Organizations should ensure that their sustainability reporting systems comply with data privacy regulations and protection as well as are secure from data breaches (Ahmad et al., 2023). The standardization of sustainability reporting is crucial if different data are used by organizations. Ensuring data accuracy in data analytics systems used for sustainability reporting is crucial for maintaining credibility, making informed decisions, and achieving meaningful ESG impact. ESG continuous auditing enhances ESG disclosure accuracy and provides stakeholders with added assurance. Therefore, to identify sustainability risks and opportunities, organizations should create data-driven insights. This will help them make well-informed decisions that will enhance their performance in terms of sustainability.

6. Conclusion

The study proposed a conceptual framework for monitoring corporate ESG performance. The application of emerging technologies, such as artificial intelligence, can provide real-time insights into sustainability performance, allowing businesses to quickly modify their sustainability strategy. Future research will involve the validation of the developed framework

and the development of a machine learning prediction system to monitor ESG performance for Tanzanian banks to enhance data-driven decision making.

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Contribution of the Waste Management on Job Creation and Anthropo-Social Circular Economy

L. Hakizimana
University of Technology and Arts of Byumba, Byumba, Rwanda

Abstract: Globally, waste management is a challenge that affects the world and specifically in Rwandan rural areas. The lack of proper waste management systems has led to environmental degradation, health hazards, and economic losses. This study was conducted in a small city of Byumba, which has the perspective of improving its way of waste management in rural areas through Gicumbi Agriculture Production Market (GAPM) Ltd. In order to achieve the objectives, the data were collected from the field through the questionnaire that was administered to a sample of 14 staff of GAPM Ltd and its beneficiaries. The collected data were processed quantitatively and qualitatively. The findings showed that the waste management techniques used by GAPM Ltd are landfill (100%), re-use (100%), recycling (100%), disposal (71.2%), composting (64.3%) and recovery (57.1%). The waste management of GAPM Ltd contributes to an anthropo-social circular economy in the following ways: job creation (100%), environmental protection (100%), resource conservation (85.7%), social well-being and health (78.6%), economy generation (71.4%) and community engagement (57.1%). Having achieved all objectives and verified all hypotheses, it was suggested that the government should continue sensitizing people about the role of waste management in their socio-economic sustainability.

Keywords: Waste Management, GAPM Ltd, Anthropo-social, Circular Economy, Job Creation

1. Introduction

Waste management is the process of collecting, transporting, processing, recycling, and disposing of waste materials in a way that minimizes their impact on the environment and public health. The management of waste is key for sustainable development and reducing the negative effects on the environment. Waste can come from various sources, such as households, industries, construction sites, hospitals, and other institutions. Improper handling and disposal of waste can lead to pollution, environmental degradation, health hazards, and resource depletion (Ntuli & Mbohwa, 2019).

The following hypothesis guided this study: Waste management can contribute to Job Creation and Anthropo-Social Circular Economy. The study was guided by the following three specific questions: What are waste management techniques used for anthropo-social development? Does waste management contribute to the circular economy? Does waste management contribute to job creation?

This study involved a sample of 14 respondents composed of staff members of GAPM Ltd and their stakeholders. In order to collect the data from the field, a questionnaire, being a research instrument consisting of a series of questions for the purpose of gathering information from respondents (Richard, 2014), has been used. In this research, the questionnaire has been addressed to randomly selected respondents. The questionnaire comprised both close questions

where the respondents used the tick to choose correct answer and open questions where they were free to explain the answers in their own words.

Narrative method has been used with the purpose of exploring and conceptualizing the respondents' experience. As JW Creswell states, this method helps to explore in-depth the meanings people assign to their experiences (Creswell, 1994). In this research, narrative method was used in analyzing data where it was necessary to report what the respondents had said on a certain issue. The data collected from respondents and the secondary data collected from the technique of documentation have been processed with analytical method and then interpreted.

2. Circular economy and anthropo-social findings

Items about the demographic characteristics of respondents were established in order to obtain enough information on them. The main items were gender and marital status. These items were judged very important as they allowed knowing exactly the respondents' anthropological status and then their involvement in circular economy.

2.1. Demographic findings

The results show that in GAPM Ltd, males are more involved in waste collection (57.1%) than females (42.9%), which is due to the fact that males are the first one to take responsibilities especially in households where they prefer to invest in waste collection for earning money to fulfill their responsibilities. The most important information here was not this inequality but the involvement of both genders in waste collection activities. However, these statistics show that males are more involved in the Rwandan economy than females.

Regarding the marital status of people, the findings show that 35.7% of respondents were single, 42.8% were married, 14.3% were widowed, and 7.2% were divorced (figure 1).

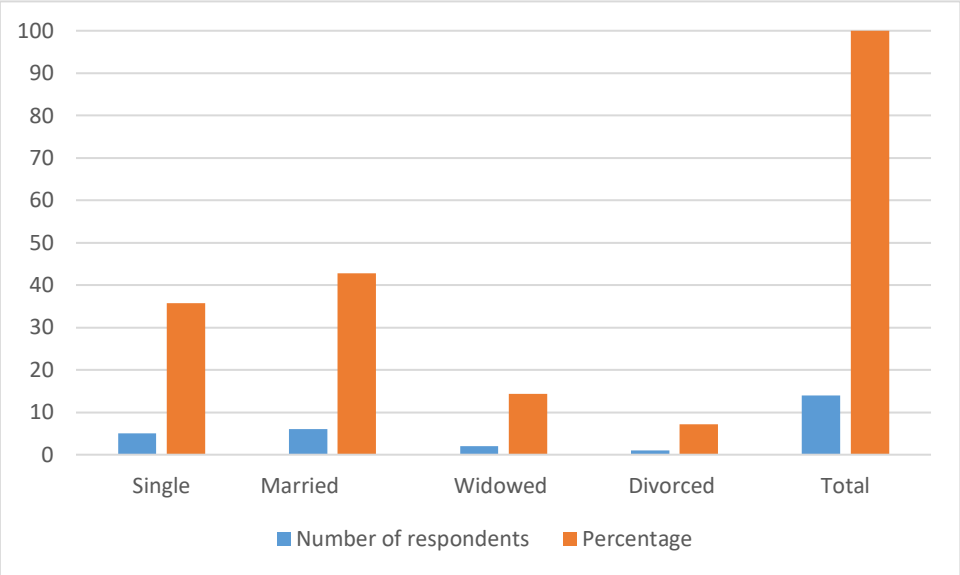

Fig. 1: Marital status of respondents

The information clarifies that the most employed in GAPM Ltd were married people. This also ensured the effectiveness of waste collection in GAPM Ltd because married people are always

conscious of what they do. However, this shows as well the marital status which is more involved in the Rwandan economy.

2.2. Techniques of waste management in GAPM Ltd and circular economy

There are several waste management techniques that are used to manage and dispose of waste in a safe and efficient manner *(Giusti, 2019).* Among them we can list landfill, incineration, waste compaction, composting and vermicomposting.

The results show that waste management techniques used in GAPM Ltd are landfill (100%); re-use (100%); suggestion of recycling (100%); recovery (57.2%); disposal (71.2%) and composting (64.3%). The results obtained are summarized in figure 2 below:

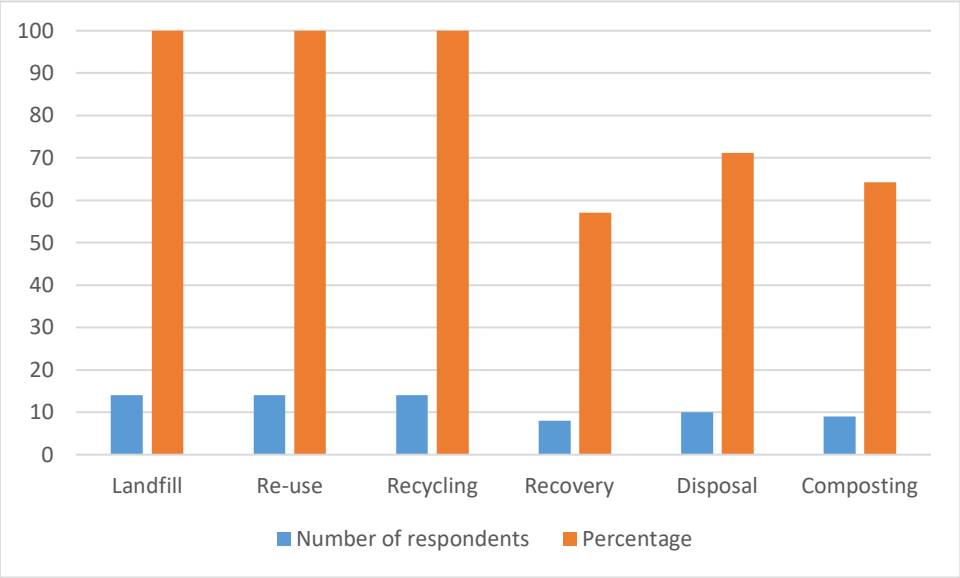

Fig. 2: Techniques of waste management

The first technique is landfill. This is the most common method of waste disposal in Byumba, where waste is buried in designated landfill sites. According to this technique, as said Weaver, the waste is compacted and covered with soil to reduce its volume and prevent odor (Weaver, 2016).

The second technique used in Byumba is incineration, which involves burning waste to convert it into ash. In Byumba, it is commonly used for organic waste in countryside. In addition, it is used hazardous waste and medical waste (Lohri & Diener, 2017). GAPM Ltd manager pointed out another technique called "recycling". This later involves the collection and processing of waste materials to create new products. According to *Giusti,* recycling is one of the most effective and useful methods that has gained popularity as a result of the introduction of environmentally friendly policies on governmental levels. In many areas, the local authorities are responsible for the collection of recyclable waste material. In some Rwandan cities, there is a proper system designed for setting up separate receptacles for each type of material that greatly reduces the risk of them mixing with those waste types that need to be discarded away. Once the materials are sorted out, they are transported to the sites where they are required *(Giusti, 2019).* In this way, the recycling is essentially the first procedure that waste materials undergo after which it is decided what will happen to the other waste product.

Another technique is composting which involves the decomposition of organic waste materials such as food waste and yard waste to create a nutrient-rich soil amendment (Weaver, 2016). This technique is common in Byumba. Composting is a popular waste management method for households in rural areas. In this method, people who own a garden make use of their food waste as compost instead of discarding it. Organic materials are collected in a suitable container and the material is left to decompose (Weaver, 2016). In general, each household in Byumba uses this technique of waste management. Once this task is completed, it is added to the soil as a means of providing natural nutrients, which assists in growing plants, fruits, and vegetables. Small farmers in Byumba use this technique to make fertilizers.

In the last decades, Rwanda embarked on converting waste into energy through processes such as incineration and gasification. In Byumba, the conversion of waste into energy consists of transforming it into biogas or biomass. This is a very useful waste management method that basically calls for the conversion of non-recyclable waste items into usable ones. This process often results in the production of energy and can be used as a sustainable power source (United Nations Environment Programme, 2016). However, in Byumba, the rate of the conversion of waste into biogas is still low.

In the line of Deveci and Sahin, local government and GAPM Ltd sensitize the households to reduce the amount of waste generated in the first place by using products and materials that are designed to last longer, and by reusing items instead of throwing them away (Deveci & Sahin, 2019).

According to Liddle, another important way of converting waste material into something useful is by converting it into animal feed (Liddle, 2017). This waste management method is effective mostly on domestic levels in Byumba, but it is also applicable to farms. Household waste, for example, vegetable peels and food scraps, are fed to small animals. Similarly, meat bones are given to dogs. Other animals, like pigs, are indiscriminate when it comes to their diet, and it is safe for them to eat most domestic waste types.

Another very significant method of waste management is in the production of firewood (United Nations, 2015). Some people, mainly in rural areas, collect discarded furniture, cut it up into pieces that are more manageable, and then use it as firewood.

2.3. Strategies for improving the circular economy

The findings from the primary data show that waste management contribute to socio-economic sustainability in the following ways: job creation (100%), resource conservation (85.7%), environmental protection (100%), economy generation (71.4%), social well-being and health (78.6%), as well as community engagement (57.1%). The results obtained are summarized in Figure 3 as follows:

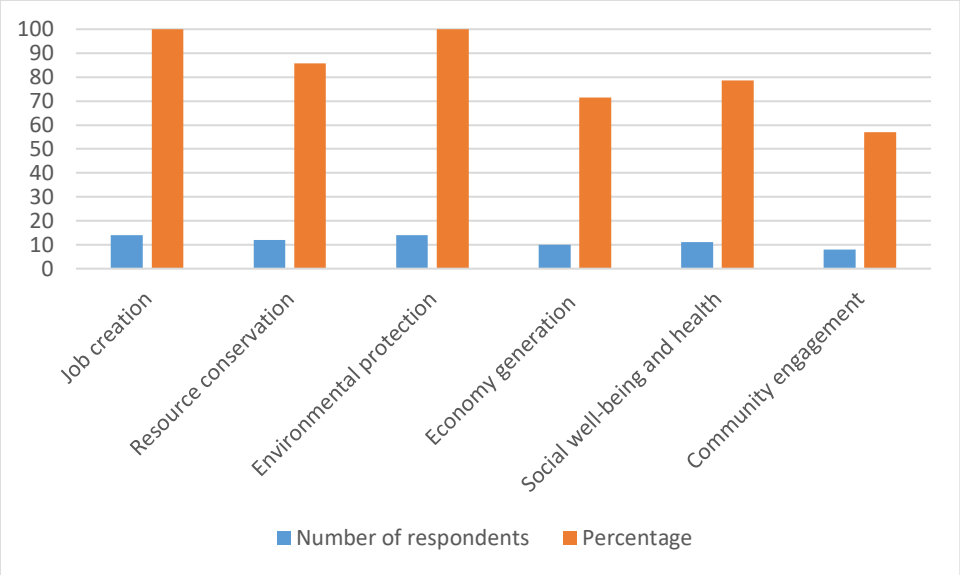

Fig.3: Contribution of waste management on socio-economic

The strategies for improving the circular economy in GAPM Ltd, corroborating with Bob, is the investments in human capital. Human capital, in the form of trainings, is more determinant of economic growth than physical capital (Bob, 2011).

2.4. From waste management to job creation

Even though unemployment exists all over the world, states and governments are trying to put in place different mechanisms to create jobs for jobless people. Among those mechanisms, we can mention public works, privatization, and self-employment mobilization (Johann, 2017).

In Byumba city, the informal sector plays a significant role in waste management. The results showed that the jobs created through waste collection in GAPM Ltd are transportation (100%), cleaning (85.7%), driving (100%), equipment maintenance (71.4%), and machine operators (78.6%). Waste management is a critical component of anthropo-social circular economy and job creation. By adopting sustainable waste management practices, progressively, the environment is protected, natural resources are conserved, economic benefits are generated, and communities are engaged in sustainable behaviors (Bhide & Narayana, 2018).

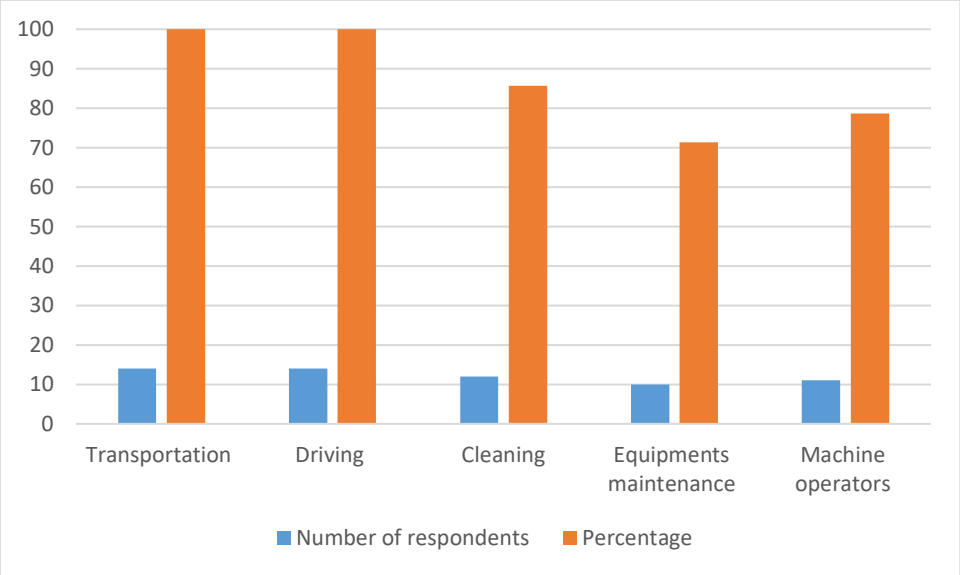

Fig. 4: Jobs created through waste collection

Concerning "transportation, driving, and cleaning", it was stated that waste management involves the collection and transportation of waste materials from homes, businesses, and public areas to treatment facilities or disposal sites. Then this process requires a workforce for packing the vehicles, which is also followed by driving the cars to the disposal sites. According to Andreas, the better qualified people are, the easier it is to find a job since the demand for well-qualified people is quite high (Andreas, 2016). The proper waste management creates employment opportunities in various fields.

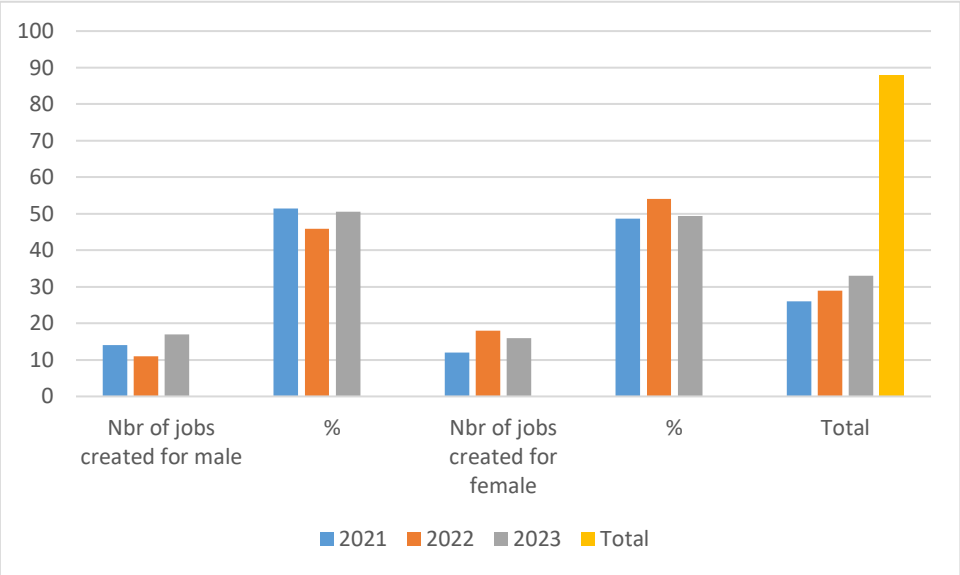

Fig. 5: Number of jobs created by gender

The findings show that in 2021, GAPM Ltd created 14 jobs for males and 12 jobs for females, making 26 jobs created this year; in 2022, 11 jobs were created for males and 18 jobs for females, making 29 jobs. In 2023, GAPM Ltd created 17 jobs for males and 16 jobs for females, and therefore 33 jobs were created. From the above results, it is deduced that through waste management, GAPM Ltd created jobs in the period 2021-2023. The most interesting thing from the above results is that both genders (male and female) are involved in jobs created by GAPM

Ltd and this contributes considerably in socio-economic sustainability. The problem of unemployment can be addressed through a set of strategies established by the governments and states (International Labor Office 2014). In the context of Byumba city, the solutions to unemployment proposed by GAPM Ltd is playing a vital role in social and economic sustainability.

3. Conclusion

This research was conducted on the contribution of Waste Management on Job Creation and Anthropo-Social Circular Economy. The number of respondents was 14 composed of staff members of GAPM Ltd and their stakeholders. We distributed the questionnaire to those respondents who in turn provided data. The data were processed quantitatively and qualitatively, and the analysis and interpretation of the results helped us to arrive at the reliable results.

Effective waste management has the potential to contribute significantly to socio-economic sustainability and job creation. However, there is a need to address the challenges to effective waste management, including inadequate infrastructure, limited financial resources, and low levels of public awareness. By promoting proper waste management practices, it is possible to create new economic opportunities, conserve natural resources, and mitigate the negative impacts of waste on the environment and human health.

The waste management of GAPM Ltd contributes to socio-economic sustainability in different ways, such as job creation, resource conservation, environmental protection, economy generation, social well-being and health, and community engagement. From 2021 to 2023, there was an increase in jobs created through waste management for both men and women; therefore, our hypothesis has been confirmed. However, the present study was not exhaustive in **matters of waste management, job creation, and anthropo-social circular economy; future research could be conducted on the challenges to effective waste management and the impact of waste on the environment, human health,** and sustainable development.

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Achieving Circular Economy Goals with ERP/SAP: A Data-Informed Approach to Procurement and Distribution

J. Babu, E. Kaaya, G. Lyakurwa, A. Sam
The Nelson Mandela African Institution of Science and Technology, Arusha, Tanzania

Abstract: The paper presents an integrated, data-informed procurement and distribution system developed for Transchem Pharmaceuticals, focusing on synchronization across branches and integration with ERP/SAP systems with a strong emphasis on sustainability. The study identifies key challenges in pharmaceutical supply chain management, such as visibility and coordination issues that cause inefficiencies and cost escalations. Through focus groups, surveys and an Agile Approach using Extreme Programming, the research developed a system that integrates with ERP/SAP platforms to enhance security, user satisfaction and compliance. The system offers valuable insights into consumer preferences and demand patterns, supports environmental and social sustainability through efficient inventory management and fosters a circular economy. Findings highlight the benefits of real-time data for synchronized stock control and strategic planning, with future research proposed in machine learning for demand forecasting, blockchain for transparency and robotic process automation for optimization.

Keywords: Procurement, Distribution, Stock Control, Supply Chain Management, Pharmaceutical Industry.

1. Introduction

Drug management in pharmacies plays a critical role in hospital and pharmacy administration, representing a substantial portion of funding beyond medical services such as surgeries and other treatments. Effective drug management involves the rational selection, efficient quantification and forecasting, procurement, storage and distribution of pharmaceuticals (WHO, 2019). This comprehensive process ensures that medications are available in the right quantities, of the appropriate type and quality and used in a rational manner. Ineffective drug management can lead to significant financial repercussions for pharmacies, whereas an optimized system can prevent drug shortages and surpluses, thereby enhancing overall operational efficiency.

In Kenya, the Pharmacy and Poisons Act CAP 244 mandates the Pharmacy and Poisons Board (PPB) to oversee the regulation of medical products and health technologies. This regulatory framework ensures that the quality of medical products and the integrity of the distribution chain are preserved from manufacturing to the final dispensation to the end user (Pharmacy and Poisons Board of Kenya, 2019). However, managing procurement, distribution, and inventory across numerous branches is a complex endeavor that necessitates real-time data access and informed decision-making (Muhwezi et al., 2023).

Recent advancements in technology reveal the potential of integrated data-driven systems, such as ERP (Enterprise Resource Planning) and SAP (Systems, Applications and Products), to address these complexities. By improving inventory management and reducing excess inventory, these systems offer significant benefits to pharmaceutical supply chain management (Yousefi Sarmad et al., 2023; Balkhi et al., 2022). An effective ERP/SAP integration can

streamline processes and enhance operational efficiency, but it also presents technical challenges that must be navigated.

This study examines how integrating ERP/SAP platforms can address challenges in the pharmaceutical supply chain and promote sustainability through efficient inventory management, sustainable procurement, and contributions to the circular economy. It analyzes technical integration aspects, identifies challenges, and proposes solutions to improve drug management practices and advance sustainability in the pharmaceutical sector.

2. Review of related Works

Information systems are integral to managing procurement and distribution processes in the pharmaceutical industry. Existing literature reveals a range of challenges and gaps in inventory control and supply chain management that have been the focus of recent research. One study highlights that data integration issues in Enterprise Resource Planning (ERP) systems pose significant challenges for harmonizing data across different functions within pharmaceutical organizations (Bandara et al., 2023). Their study emphasizes that while ERP systems are designed to consolidate information from various sources, discrepancies in data formats and integration processes often lead to inefficiencies and data silos. This limitation impedes the ability to achieve a unified view of inventory and procurement processes, which is essential for effective decision-making.

Another study further identifies deficiencies in inventory management systems, particularly the lack of real-time tracking capabilities (Shashi, 2023). Traditional inventory management systems often struggle with outdated information, which can result in inefficiencies such as stockouts and overstock situations. The inability to track inventory in real time limits the effectiveness of inventory control measures and forecasting accuracy, creating a pressing need for more advanced tracking and data analysis techniques.

The integration of inventory management systems with supply chain management systems as a potential solution for improving demand forecasting accuracy and reducing inventory holding costs (Malik et al., 2022). They argue that while integration can enhance demand forecasting and inventory optimization, many existing systems fail to fully leverage data analytics for predictive modeling. This gap underscores the need for more sophisticated systems that not only integrate various functions but also apply advanced data analytics to optimize inventory management.

Data analytics and data-driven decision-making are increasingly recognized for their role in enhancing pharmaceutical procurement and distribution processes. Gaps exist in predictive modeling within inventory management systems, where many systems lack robust predictive algorithms that can anticipate future inventory needs based on historical data (Djordjevic et al., 2022). Similarly, challenges related to data quality in implementing data technology solutions are also common, emphasizing that poor data quality undermines the effectiveness of data-driven decision-making (Dong et al., 2023). Emphasis was placed on the benefits of data analysis in enhancing demand forecasting accuracy (Jackson et al., 2023) and identifying cost-saving opportunities (Musanga, 2022). Their research shows that while data analytics offers significant potential for enhancing supply chain management, there remains a challenge in integrating these tools with existing systems to achieve comprehensive and actionable insights.

Stakeholder collaboration in overcoming technical hurdles such as data format discrepancies and achieving effective system integration is vital (Xu et al., 2023; Setyawan et al., 2022). Their work reveals that while integrated procurement and distribution information systems offer potential efficiency gains, the success of these systems often depends on the ability of various stakeholders to work together towards common goals. There is a necessity of synchronized stock control across company branches to meet customer demand effectively. Their study identifies real-time tracking as a crucial element for maintaining accurate stock levels across multiple locations (Ramadhan et al., 2023). Similarly, data analytics can enhance demand forecasting and optimize stock levels, yet many organizations have yet to fully implement these solutions (Mushi & Nsimbila, 2022; Lee et al. 2023).

Case studies of integrated procurement and distribution information systems provide insights into the benefits and challenges of these systems (Omer et al., 2021) and (Xie et al., 2022). While these studies report improvements in inventory management and supply chain visibility, they also reveal persistent technical integration challenges and the need for advanced solutions (Nittari et al., 2022).

In light of these challenges, this study discusses the development of an integrated system aimed at addressing key issues identified in the literature. The proposed system tackles the problem of data integration within ERP frameworks by providing a centralized and standardized approach to data management across different branches of Transchem Pharmaceuticals. By implementing a comprehensive solution that includes features such as a function for alerting personnel about stock levels and a GPS IoT tracking mechanism for real-time monitoring, this study seeks to overcome existing gaps in inventory management and supply chain optimization.

This study develops an integrated system for Transchem Pharmaceuticals to enhance real-time tracking, improve demand forecasting with advanced data analytics and promote stakeholder collaboration for effective system integration. By addressing limitations in existing systems, the study aims to reduce resource wastage, eliminate data redundancy and achieve operational efficiency and cost savings. The proposed system supports data-informed decision-making for better procurement, inventory management and distribution processes, leading to optimized supply chain operations, reduced costs, increased sales revenue and improved customer satisfaction, ultimately advancing inventory management practices and sustainable supply chain management in the pharmaceutical industry.

3. Materials and Methods

This study employed a qualitative research design to explore and address the challenges associated with the procurement and distribution processes at Transchem Pharmaceuticals. The research framework was centered on understanding the inefficiencies within the existing system and developing a new, integrated solution to improve operational effectiveness. The primary objective was to design a system that would enhance procurement, inventory management and distribution processes, ultimately leading to reduced costs, improved customer satisfaction and streamlined operations across the company's branches. The central hypothesis posited that an integrated data-informed system would overcome existing inefficiencies and lead to better management of resources and processes.

The new system was developed using the Agile Extreme Programming (XP) methodology, chosen for its emphasis on iterative development, continuous feedback, and stakeholder collaboration. This approach enabled frequent revisions based on user input, ensuring the

system met evolving needs. XP's focus on simplicity, high-quality coding, and pair programming helped create a robust, user-friendly system. Regular testing and stakeholder feedback allowed for continuous improvement, addressing the complex requirements of Transchem Pharmaceuticals effectively.

Data collection for this study used both primary and secondary sources to understand the current system's deficiencies and new system requirements. Primary data was obtained through semi-structured interviews and focus groups with Transchem Pharmaceuticals' personnel, along with observations of real-time operations and a benchmark test comparing the new system's performance against the existing one. Secondary data was collected from document analysis of reports, memos and case studies on procurement and distribution processes to identify system strengths and weaknesses.

For data analysis, Google Forms was utilized to facilitate the collection and organization of qualitative feedback from interviews, focus groups and surveys. The data collected was analyzed using content analysis techniques to identify common themes and patterns related to system requirements and usability. This approach enabled a detailed examination of participant responses, revealing insights into the system's effectiveness and areas for further refinement. The use of content analysis allowed for systematic interpretation of qualitative data, ensuring that the findings were both reliable and valid.

The system is accessed by both regular staff and the admin. The web user interface is accessed from an internet browser. HTML, CSS, JavaScript and Vue.js were used to achieve the front end. The backend used Python with Django Framework. It also has a cloud server and cloud storage as seen in Fig. 1.

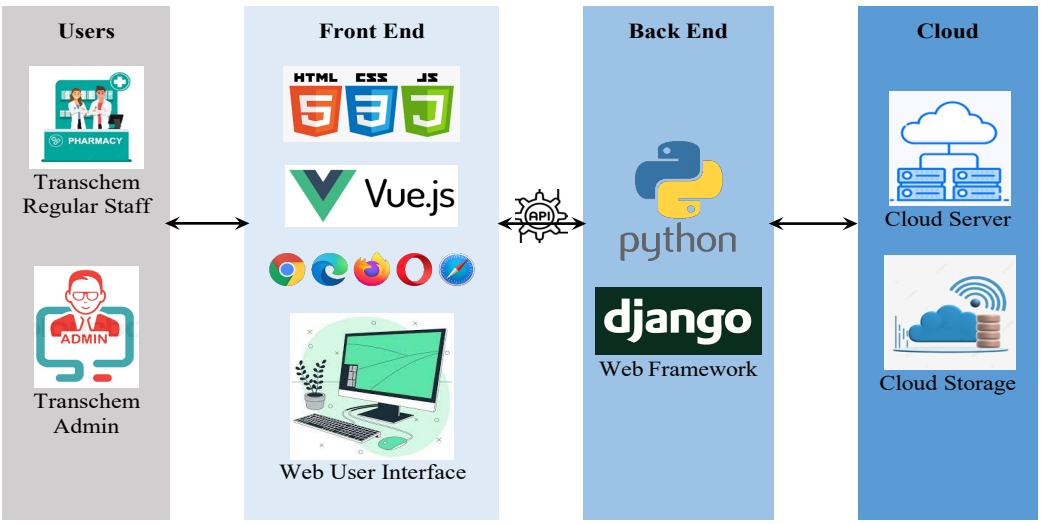

Fig. 1: Proposed System Design

4. Results and Discussions

The implementation of the system has yielded significant improvements in various operational metrics. User satisfaction with the new system was assessed through a post-implementation survey, revealing substantial improvements in several key areas.

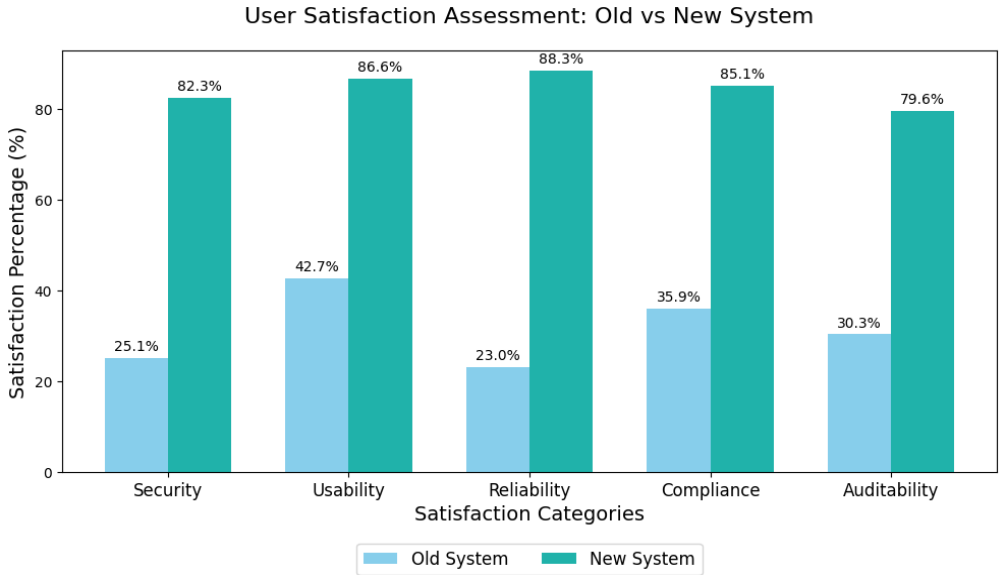

Fig. 2: User Satisfaction Assessment of Old versus New System

Satisfaction with system security increased from 25.1% to 82.3%, reflecting enhanced access controls, encryption and authentication mechanisms. Usability satisfaction rose from 42.7% to 86.6%, attributed to a comprehensive redesign of the user interface and improved user experience. Reliability satisfaction improved from 23.0% to 88.3%, owing to better error handling and fault tolerance. Finally, compliance satisfaction increased from 35.9% to 85.1%, with the system now adhering to relevant industry standards and regulations and auditability satisfaction rose from 30.3% to 79.6%, thanks to the implementation of robust audit trails and monitoring mechanisms.

The practical application of the new system at Transchem Pharmaceuticals demonstrates its effectiveness in real-world scenarios. Key challenges included outdated processes, inefficiencies in stock control and compliance issues. The system's implementation involved extensive stakeholder collaboration, iterative testing and comprehensive training, resulting in notable operational improvements and user satisfaction. The system's ability to track goods from suppliers to end consumers has improved traceability, reduced waste and enhanced overall supply chain coordination. Enhanced security measures have bolstered data protection, instilling greater confidence among users and stakeholders.

The new system promotes sustainability and the circular economy by improving inventory management to reduce overstocking and waste and integrating with sustainable procurement practices to source eco-friendly products. It adheres to industry standards like Good Distribution Practice (GDP), ensuring ethical business practices. Enhanced performance and reduced lead times lower energy consumption and resource use, contributing to a more sustainable operation. This integrated, data-informed system not only boosts operational performance but also supports Transchem Pharmaceuticals' commitment to environmental and social governance (ESG) principles.

5. Conclusion and Future Works

The Integrated Data-Informed Procurement and Distribution Information System was meticulously designed, developed and tested to enhance Transchem Pharmaceuticals'

procurement and distribution processes while ensuring synchronized stock control across its branches. The system's integration with ERP/SAP platforms supports real-time, data-informed decision-making, significantly improving operational efficiency, reducing waste and contributing to sustainable procurement practices and the circular economy. The system demonstrated excellent user-friendliness, reliability, efficiency and effectiveness, outperforming existing procurement and distribution processes. Key findings highlight the system's ability to increase competitiveness and profitability for Transchem Pharmaceuticals while aligning with industry standards and sustainability goals. Future research should explore system scalability, machine learning-driven predictive demand forecasting and the integration of emerging technologies like blockchain for transparency and robotic process automation to streamline routine processes. Extending the study to various industries and geographical regions could provide broader insights and applications.

6. Acknowledgement

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Decades of Plastic Pollution in a Coastal Wetland in Ghana: Implications for the Circular Economy

D. Nukpezah, N. Abrahams & S. Koranteng
University of Ghana, Institute for Environment and Sanitation Studies, Accra, Ghana

Abstract: Plastic pollution harms wetland ecosystems, reducing their ability to provide essential ecosystem services. Microplastics in sediment cores provide insight into the historical record of pollution while macroplastic surveys are important ways of establishing the amount of discarded plastic in the environment. We assessed the provenance and occurrence of macroplastic and the polymer composition and historical trend of microplastic pollution in a coastal wetland in Ghana using standard methods. The result showed that plastic pollution is of grave concern in the Densu Delta coastal wetland and that most of the plastic pollution is land based coming from within the country. Polymer composition analysis conducted revealed microplastic types consistent with plastic types found in the waste stream in Ghana. The sediment age profile determination revealed that plastic pollution of the coastal wetland is a long standing one which can be traced back to several decades, to at least 1975. We recommend that policies that are geared towards waste reduction, reuse, recycle and recovery should be enacted. In addition, fiscal measures such as plastic tax, and fees as well as mandatory extended producer responsibility requirements for industries should be instituted to regulate the use and disposal of plastic in the country.

Keywords: Plastic, Pollution, Wetland, Circular Economy, Ghana

1. Introduction

Wetlands are important ecosystems recognized for their functions including water storage, storm protection, flood mitigation, shoreline stabilization, and erosion control (Mitsch & Gosselink, 2015). They also generate important products such as wildlife resources, fisheries and water supply. The Densu Delta wetland in Accra, Ghana is an internationally recognized and ecologically sensitive wetland (Ramsar site) that provides essential ecosystem services including flood retention and habitat support for migratory waterfowls. However, the wetland faces tremendous environmental impacts including plastic pollution that affects essential ecosystem services in the wetland. Macroplastic litter (plastic litter greater than 5 mm in diameter) as well as degraded plastic less than 5 mm in diameter (microplastics) are known to cause detrimental impacts on ecosystems including wetlands. Macroplastic litter has been reported to cause entanglement of aquatic species such as fish (Mattsson et al., 2015). Microplastics on the other hand get consumed by fish which are exposed to them (Musah et al., 2021). This has been found to cause malnourishment and the impairment of their reproductive ability (Werner et al., 2016). Thus, the functioning of wetlands that serve as spawning and breeding ground for several species are compromised due to both macroplastic and microplastic pollution.

The content of plastics in the waste stream in Ghana has increased from about 3% in 1994 to 14% in 2014 (Miezah et al., 2015). This sharp increase in plastic waste in Ghana is a reflection of the changing trends in product packaging as most consumable products are now packaged in plastics. It is also a consequence of the high volumes of imported plastic into the country which

has increased from about 20 million kg in 2004 to 55.5 million kg in 2013, with a sharp peak of 171.3 million kg in 2015 (Hogarh, 2015). Plastic pellets which are used as raw material for the production of various plastic products are mainly imported into the country from China and India (Ghana Commercial Bank, 2022). About 86% of the total plastic waste generated in Ghana is indiscriminately discarded ending up in oceans, estuaries and freshwater habitats (World Bank Group, 2020).

Despite the above statistics, there is no determination regarding the extent of the plastic waste problem in terms of the source of plastic pollution to the wetland; the nexus between macroplastic and microplastic pollution and the temporal dynamics of plastic pollution which are important steps that must be understood in order to proffer appropriate solutions to the plastic problem.

Thus, in this study, we assessed the provenance of macroplastic and the historical trend of microplastic pollution in a coastal wetland as basis for appropriate policy action. Based on our findings, we proposed policies and strategies anchored on circular economy principles and life cycle thinking as a panacea to managing plastic waste and promoting sustainable development in Ghana. In addition, our submission contributes to the dialogue and discourse on plastic pollution and the concerted global effort needed to address it.

2. Methodology

The study was conducted within the Densu Delta coastal wetland located in the Southwestern part of Accra within the Greater Accra region of Ghana. The wetland is recognised internationally under the Ramsar Convention of Wetlands of International importance especially as waterfowl habitats. The wetland (Ramsar site) has an area of approximately 46.2 km^2 and is characterised by a lagoon, sand dunes, flood plains, freshwater marsh, scrub and salt pans (Blankson et al., 2022).

2.1. Macroplastic Litter Assessment

Macroplastic litter assessment was conducted according to the Protocol of OSPAR Commission (2010). Litter abundance and diversity were determined at Panbros, a mangrove habitat within the wetland from August to October 2023. *Abundance* refers to the overall number of individual macroplastic litter at each sampling site while *diversity* refers to the range of types of macroplastic litter at each sampling site (Nukpezah et al., 2022). Prior to sampling each month, all litter present at the sampling site was removed. Thus, only freshly accumulated macroplastic litter was assessed. At the sampling site, a 50 m by 30 m transect was established parallel to the water mark according to Blettler et al. (2017). In each given month of macroplastic sampling, all visible freshly accumulated macroplastic litter (larger 2.5 cm in diameter) in the established 50 m by 30 m transect were collected (Blettler et al., 2017; Opfer et al., 2012) and sorted into categories based on their functional use and subsequently counted manually to determine the abundance and then recorded on predesigned data sheets adapted from OSPAR Commission (2010) guidelines.

The monthly rate of macroplastic litter accumulation at each sampling site (r) was calculated using the formula (Blettler et al., 2017):

$$r = \frac{Total\ Number\ of\ Macroplastic\ Litter\ Counted\ at\ Sampling\ Site\ per\ Month}{Area\ of\ Transect} \quad (1)$$

The calculated monthly rates of macroplastic litter accumulation at the sampling site was expressed in items/m^2/month.

2.2. Source Identification of Macroplastics

In this study, collected macroplastics were manually inspected for company logos/symbols and categorised into *Unidentified, Local* and *Foreign* brands. *Unidentified* represented macroplastics which could not be recognised due to them being unbranded or their logos being illegible as a result of exposure to harsh environmental conditions. The categorisation was done to help in the determination of the origin of the plastic i.e., whether macroplastic litter originate from the geographical location where they are found or whether they were possibly transported from another location (Veiga et al., 2016). Such an assessment is useful in serving as basis for policy makers to tackle the issue of plastic waste accumulation from its source.

2.3. Determination of Microplastic Abundance

Sediment Sampling

Three replicates of sediment core samples were collected at Panbros, a mangrove habitat within the coastal ramsar wetland at a depth of 30 centimetres (cm) in September, 2023. The choice of Panbros which forms the main catchment area of the wetland was due to the fact that mangrove regions are among the hotspots for the accumulation of microplastics in sediments (Dung et al., 2021). The sediment core samples were taken with the aid of a sediment corer which has an internal diameter of 8.5 cm and length of 60 cm. The sediment core samples were collected in a careful manner to ensure that the depositional sequence remained intact after which the 30 cm-long sediment core was extruded from the sediment corer and sliced at 5 cm intervals along the length of each core (Li et al., 2020). Thus, 3 replicates x 6 slices, making a total of 18 sediment core slices were obtained for analysis.

Historical Trend in Microplastic Accumulation

In order to establish the historical trend in microplastic accumulation, sediment accumulation rates were determined and used to construct an age-depth profile of sediment cores. This was complemented by laboratory analysis. The step by step approach used, is illustrated in Fig. 1. In order to calculate the linear accumulation rate, a specific mineral density of 2.65 g/cm3 was used (Szmytkiewicz & Zalewska, 2014).

Data Analysis

The normality of the data was determined using the Shapiro-Wilk test. Pearson product correlation was conducted to establish the relationship between the mean microplastic abundance and the sediment core depth. On the otherhand, linear regression analysis was undertaken to determine the predictive relationship between sediment core depth and mean microplastic abundance. Both analyses were done using IBM SPSS software version 25. All statistical tests were conducted at 5% level of significance.

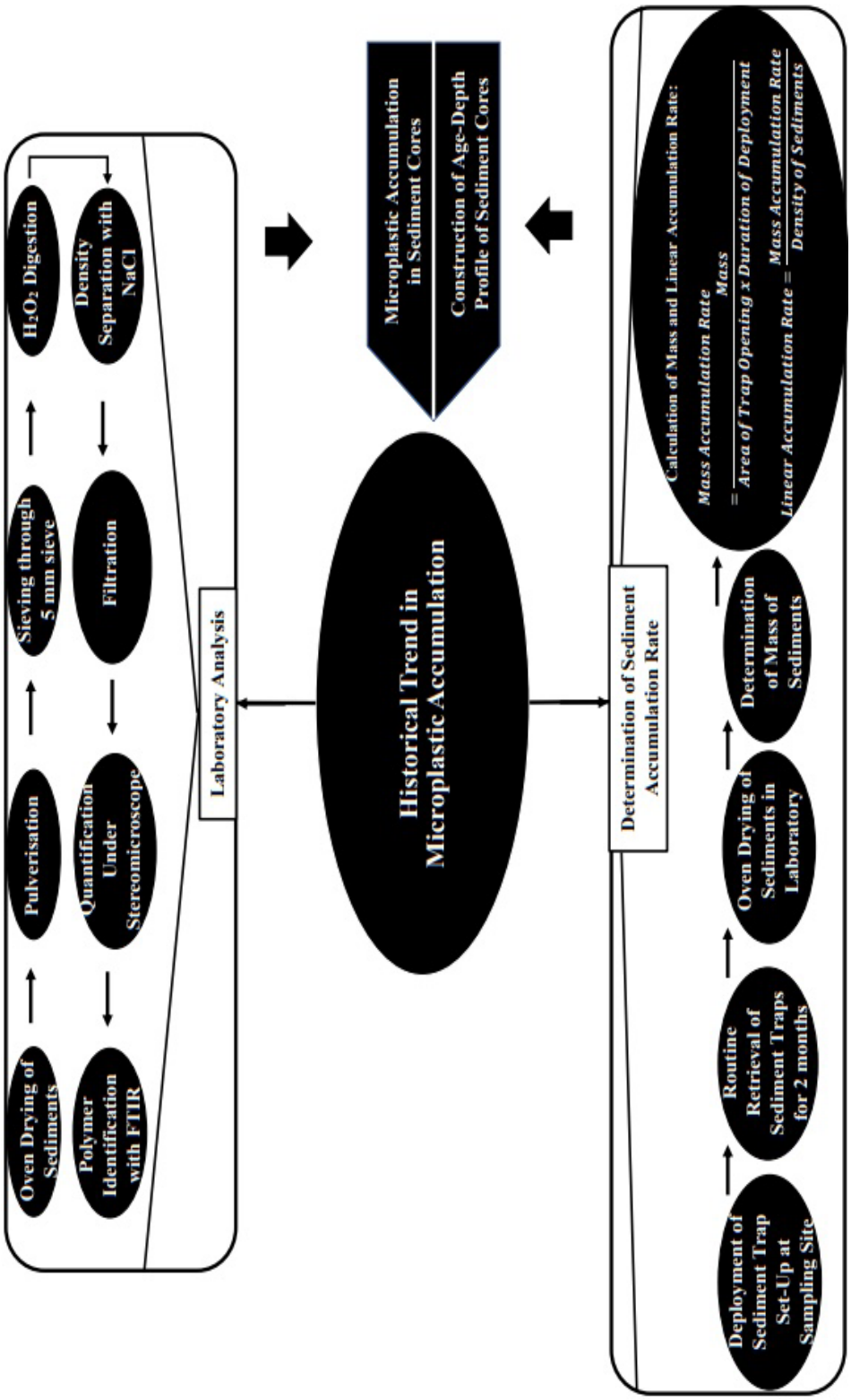

Fig:1 Diagram showing how the historical trend in microplastic accumulation in the study area was determined

3. Results and Discussion

3.1. Macroplastic Abundance and Diversity

The study recorded a total of 762 macroplastic items in 17 litter categories (Fig. 1) during the study period at Panbros. The highest abundance was recorded in September (n = 301) and the second highest abundance was recorded in August (n = 253) while the lowest abundance was recorded in October (n = 208). Differences in abundance is attributable to varying levels of human activities in the various months and the highest abundance recorded in September corresponds with a peak in these actvities. The monthly rates of macroplastic litter accumulation were 0.17 items/m^2/month in August, 0.20 items/m^2/month in September and 0.14 items/m^2/month in October with a mean of 0.17 ± 0.03 items/m^2/month. In a similar study, Abrahams (2024) recorded higher values of 0.26 ± 0.08 items/m^2/month and 0.43 ± 0.08 items/m^2/month at Tsokome and Densu Estuary respectively.

In terms of diversity, over the entire three months sampling period, a total of seventeen (17) macroplastic litter categories (based on OSPAR Commission 2010 classification) were recorded. These categories included drinks/water bottles, caps/lids, water sachets, black polythene bags, small bags, alcohol sachets, and several others and are shown in Fig. 2 and 3. Across the three (3) months sampling period, water sachets were the most dominant plastic litter category recorded (n = 193). The highest amount of water sachets was recorded in the month of September (n = 78) while the second highest amount was recorded in the month of August (n = 63) and the lowest amount was recorded in the month of October (n = 52). Drinks/water bottles was the second most dominant plastic litter category recorded across the three months sampling period at Panbros (n = 147). Drinks/water bottles were most abundant in September (n = 62). The second highest amount of drinks/water bottles was recorded in August (n = 54). The least amount on the other hand was recorded in October (n = 31). These findings are consistent with the findings of Nukpezah et al. (2022) who reported a preponderance of plastic bottles and sachet which are commonly used in Ghana to package water, in a coastal lagoon.

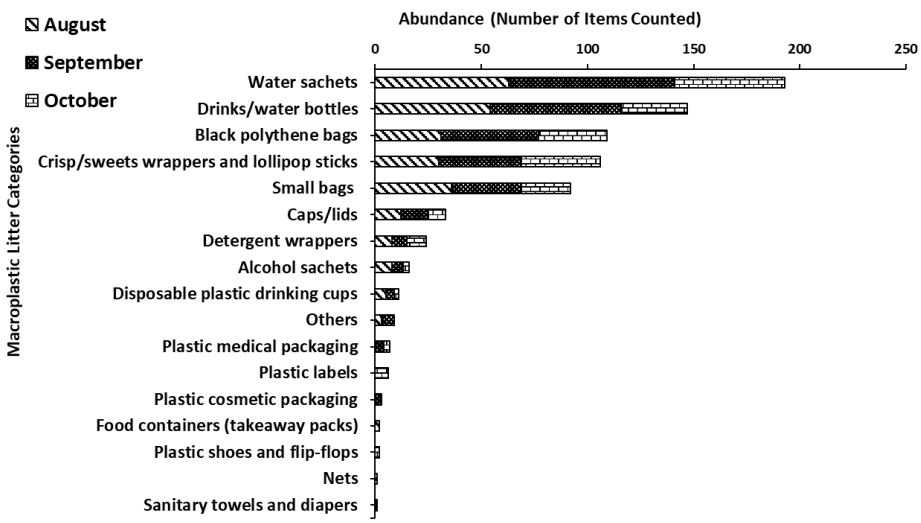

Fig. 2: Macroplastic Litter Categories Recorded at Panbros during the study

3.2. Macroplastic Brands Origin

Of the seventeen (17) macroplastic litter categories identified at Panbros over the three months sampling period, nine (9), constituting 53% were composed of unbranded items. These unbranded items included black polythene bags, small bags, disposable plastic drinking cups, plastic cutlery and straws, rope, foam, net, amongst others that are common on the Ghanaian market. The remaining eight (8) macroplastic litter categories identified are composed of items which are typically branded. Some of the brand names were illegible due to exposure to harsh environmental conditions and were therefore unidentifiable. The macroplastic categories whose brand names were most identifiable were drinks/water bottles, water sachets, alcohol sachets and detergent wrappers. These are mostly local brands with brand names such as *Belcola, Voltic, Beta Malt, Belaqua, Malta Guiness, Aqua Splash* and *Special Ice* for drinks/water bottles category; *Sprint Ice, Everpure, Favor Ice and Voltic Cool* for the water sachets category; *Kasempa, Adonko, Goal and Striker,* under the alcohol sachets category and finally, *Lavita, MOK and So Klein* were the top brands identified under the detergent wrappers category. The dominance of local branded plastic waste in the study area suggests that these plastics originate mostly from within the country and have not been carried by ocean current into the country. Indeed, some of the macroplastic litter at the sampling locations may have been generated directly within the Ramsar site while the remaining portion may have been transported from inland areas via surface runoff, the Densu River or wind to the Ramsar site or could have also been transported from the ocean to the Ramsar site (Ford et al., 2022).

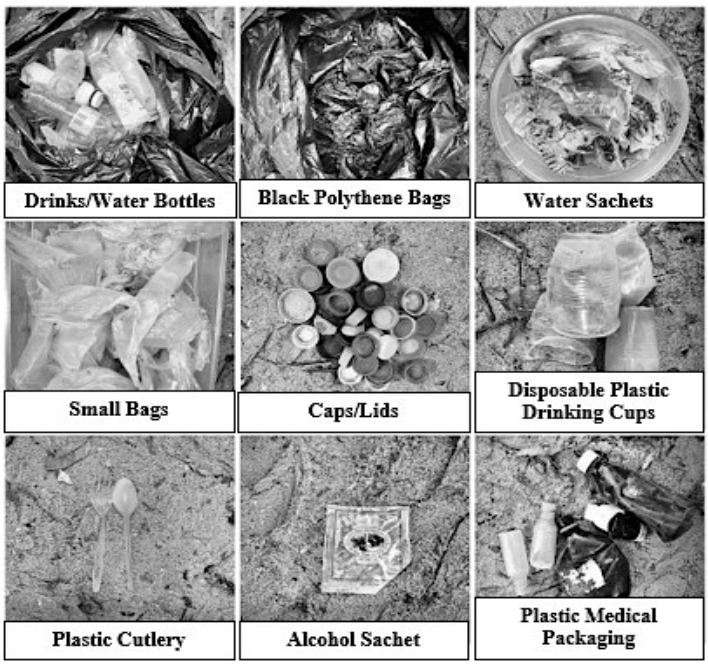

Fig. 3: Samples of Some of the Macroplastic Litter Categories Recorded in the wetland

3.3. Microplastic Abundance

A total of 278 microplastics were found in all the sediment cores in the study area. The mean microplastic abundance in sediment cores sampled at Panbros exhibited an enrichment in microplastics in the top layer (0 – 5 cm); with a continuous decrease in microplastic abundance to the last layer (25 – 30 cm) as shown in Tab. 1. There was a very strong negative correlation and a statistically significant relationship (Fig. 4) between the mean microplastic abundance and sediment core depth ($r = -0.931$, $p = 0.007$). Similarly, simple linear regression analysis,

showed that the sediment core depth accounts for 86.8% of the variance in the mean microplastic abundance ($r^2 = 0.868$, F (1, 4) = 26.197, p = 0.007) implying that sediment core depth significantly predicted microplastic abundance at the study site (ß = -1.523, t (4) = -5.118, p = 0.007) as shown in Fig. 5. These results suggest that greater sediment core depth leads to lesser microplastic abundance at the Panbros sampling site.

The occurence of microplastics and also macroplastic in the study area is of grave concern for several reasons. For example, the consumption of microplastics by aquatic organisms like fish and other animal species such as water birds have been reported to limit their ability to detect hunger, to carry out digestion and reproduction and has again been found to cause abnormalities in their DNA and also cause death (Nukpezah et al., 2022; Werner et al., 2016).

Tab. 1: Mean Microplastic Abundance per Sediment Core Depth

Sediment Core Depth (cm)	**Panbros (Mean ± Standard Deviation)[1]**
0 – 5	19.00 ± 1.73
5 – 10	17.33 ± 1.53
10 – 15	16.00 ± 2.00
15 – 20	15.67 ± 4.04
20 – 25	14.67 ± 2.08
25 – 30	10.00 ± 2.00

[1]Expressed in Microplastics per 50 Grams of Sediments

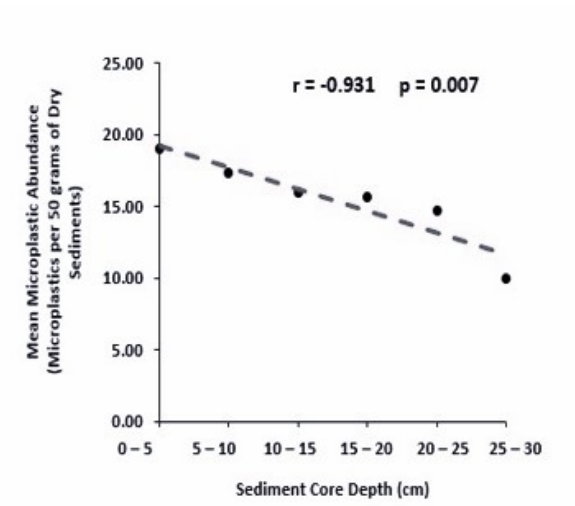

Fig. 4: Correlation Between Mean Microplastic Abundance and Sediment Core Depth at Panbros Sampling Site

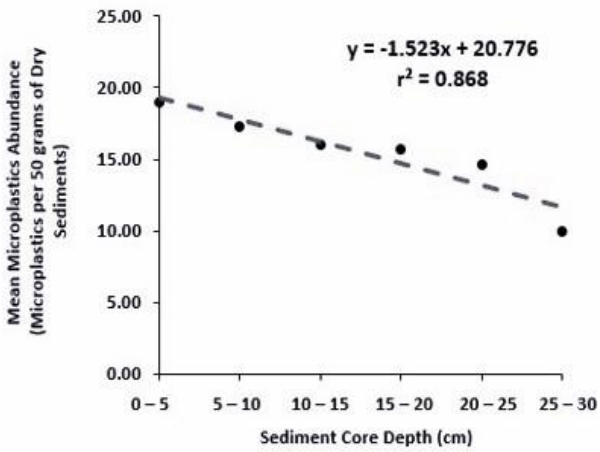

Fig. 5: Simple Linear Regression Between Mean Microplastic Abundance and Sediment Core Depth at Panbros

3.4. Linear and Mass Accumulation Rates of Sediments

The mean mass accumulation rate of sediments was 1.63 ± 0.23 g/cm^2/yr and its mean linear accumulation rate was 0.62 ± 0.09 cm/yr (Tab. 2). Based on the linear accumulation rate (0.62 cm/yr), each 5 cm interval of the sediment core was equivalent to ~8 years of sediment accumulation (Tab. 3).

Tab. 2: Mass and linear Accumulation Rates of Sediments in Sediment Traps deployed at the study site

Panbros			
Duration of Trap Deployment	Mass (g)	Mass Accumulation Rate (g/cm^2/yr)	Linear Accumulation Rate (cm/yr)
One (1) Month	11.70 ± 0.81	1.79	0.68
Two (2) Months	19.27 ± 1.07	1.47	0.55
Mean	15.49 ± 5.35	1.63 ± 0.23	0.62 ± 0.09

Tab. 3: Age-Depth Profile of Sediment Cores at Panbros

Sediment Core Depth (cm)	**Year**
0	2023
5	2015
10	2007
15	1999
20	1991
25	1983
30	1975

3.5. Historical Trends in Microplastic Accumulation

The 30 cm sediment core taken within the wetland at Panbros represented a deposition period spanning 1975 to 2023. The year 2023 corresponded with the surface sediments (0 cm) while 1975 corresponded with the deepest sediments (30 cm). This means that microplastics have accumulated in the wetland from at least 1975. The highest mean microplastic abundance of 19.00 ± 1.73 microplastics per 50 grams of sediments was recorded in the topmost layer (0 – 5 cm) which corresponds with 2023 to 2015. This was followed by a marked consistent decrease in the mean microplastic abundance to the last layer (25 – 30 cm) that corresponds with 1983 to 1975 which had the lowest mean microplastic abundance of 10.00 ± 2.00 microplastics per 50 grams of sediments. This historical trend in microplastic accumulation in the study area reveals a consistent growth in microplastic abundance from 1975 to 2023. Fig. 6 illustrates the age-depth profile of the mean microplastic abundance in the sediment core at Panbros. The consistent increase in microplastic abundance in the sediment cores from 1975 till date could be attributed to the steady growth in plastic consumption and the release of plastic waste in Ghana from the 1970s till date (Musah et al., 2021). A similar relationship between plastic consumption and microplastic abundance was observed in sediment cores in other parts of the world (Dung et al., 2021).

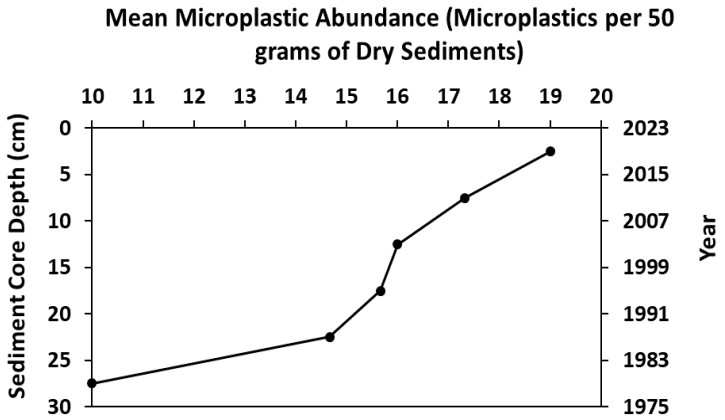

Fig. 6: Age-Depth Profile of Mean Microplastic Abundance in Sediment Core from Panbros

3.6. Polymer Composition of Microplastics

The types of synthetic polymers identified in the microplastics samples subjected to FTIR analysis were polyethylene, polypropylene, polystyrene, polyester, cellophane and polyvinyl acetate. These polymer sub-fractions are similar to the plastics sub-fractions found in the waste stream in Ghana (Miezah et al., 2015) suggesting that the source of the microplastics is from the plastic waste stream in the country.

4. Conclusion

Conclusively, this study has established that macroplastic and microplastic pollution are problems of grave concern in the Densu Delta coastal wetland in Ghana. Most of the plastic pollutants are land based. This is confirmed by the fact that most of the macroplastic brands found at the study area are local brands. Polymer composition analysis conducted revealed microplastic types consistent with plastic types found in the waste stream in Ghana. The sediment age profile determination has revealed that plastic pollution of the coastal wetland is a long standing one which can be traced back to several decades, to at least 1975.

Given that wetlands are important carbon sinks, plastic pollution can reduce their ability to sequester carbon, exacerbating climate change. Indeed, plastic waste in the Densu Delta coastal wetland represents a loss of valuable materials that could be recycled or reused, perpetuating a linear economy approach. The plastic pollution crisis in wetlands highlights the need for circular economy approaches, such as reducing plastic use, increasing recycling, and promoting sustainable materials management practices. Our research should inform evidence-based policy and investment decision-making to ensure effective environmental management.

This study has some limitations in terms of the short duration (2 months) for the deployment of sediment traps. This relatively short period hinders the consideration of processes like resuspension which are associated with sediment deposition over long periods of time. This length may not fully capture the historical microplastic accumulation trend. In our future study, we would deploy sediment traps for a period of at least one (1) year to account for varying trends in sedimentation.

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Integrated Fleet Management System for Enhanced Security and Efficiency: A case study of Avco Investments Ltd

J.Y. Muhire, R. Sinde and E. Mkoba
The Nelson Mandela African Institution of Science and Technology,
School of Computational and Communication Sciences and Engineering,
Arusha, Tanzania

Abstract: The global transportation industry faces significant challenges with cargo theft, fuel pilferage, and vehicle mismanagement, particularly when crossing international borders. To address these issues, AVCO INVESTMENTS LTD is proposing the development of an innovative fleet management software application. This upcoming system aims to enhance vehicle tracking, optimize fuel consumption, improve maintenance scheduling, and analyze driver performance. The proposed software will leverage cutting-edge technologies such as GPS tracking, real-time data analytics, and facial recognition. Key features of the system will include real-time vehicle tracking, fuel monitoring, predictive maintenance scheduling, and driver performance analysis. The application is designed to integrate seamlessly with existing business systems, including tire lifecycle prediction and inventory management software. The primary objectives of this project are to increase operational efficiency and reduce costs. The system will provide real-time tracking and fuel consumption monitoring, potentially leading to a significant decrease in theft incidents and unauthorized vehicle use. The planned facial recognition feature will ensure that only authorized drivers operate the vehicles, enhancing security and accountability. Once implemented, the system is expected to offer predictive maintenance capabilities, which could reduce vehicle downtime and extend the fleet's lifespan. Additionally, the driver performance analysis feature is anticipated to contribute to improved safety standards and more efficient route planning.

Keywords: Fleet Management, Fuel monitoring, Tire lifecycle prediction, Cargo security, Integration with business systems.

1. Introduction

The rising tendency toward globalization has increased in logistical tasks, particularly in goods transportation. Truck transport has become the most common mode of transportation worldwide, facilitating the supply chains of many businesses and governments (Dobre et al., 2021). As global trade expands, the number of firms operating large fleets of trucks is growing, a trend expected to continue as the world becomes increasingly interconnected (Inkinen & Hämäläinen, 2020). One of the major challenges in product transportation is the theft of cargo, fuel, and other valuable vehicle parts. Despite significant efforts by many companies to ensure the safety and management of their vehicles and goods using various systems, issues of theft, disappearance, and mismanagement of cargo and logistics persist, especially when crossing international borders (Mareev & Sauer, 2018). AVCO Investments Ltd, like many other African companies, currently lacks an adequate integrated system to address problems such as fuel theft, truck tracking, and speed regulation to mitigate unintentional road hazards. To address these issues, AVCO is proposing the development of an innovative fleet management software

application. This upcoming system will aim to enhance vehicle tracking, optimize fuel consumption, improve maintenance scheduling, and analyze driver performance. The proposed software will leverage cutting-edge technologies such as GPS tracking, real-time data analytics, and facial recognition. It is expected to be essential to supply chains, potentially impacting each step of the process from logistics and lifecycle management to planning and procurement, with the ultimate goal of improving efficiency and customer satisfaction.

1.1. Problem Statement

Transportation insecurity, particularly cargo theft, poses a significant challenge to the global logistics industry. The European Commission estimates that cargo theft from road and rail transportation networks costs around €8 billion per year (TT CLUB et al., 2021). The Transported Asset Protection Association's (TAPA) 2021 Trucks Theft Report indicates a worrying trend, with cargo theft incidents increasing from 65% in 2020 to 71% in 2021 worldwide (Incident & Service, 2020). These thefts were categorized as hijacking (26%), trailer/container theft (11%), vehicle theft (9%), staff theft (7%), fuel theft (7%), and others (5%). The problem is particularly acute in Africa. Reuters reported that between January and May 2024, 66 trucks transporting copper were robbed in South Africa alone (Reuters, n.d.). This suggests that the actual number of incidents on African roads, including unreported cases, could be significantly higher. The inability to track missing vehicles effectively contributes to the persistence of this problem, as thieves can exploit the lack of real-time monitoring to their advantage. AVCO Investments Ltd, like many other African companies, faces additional challenges specific to its operations. Fuel theft from drivers is a persistent issue, especially in Africa, leading to significant financial losses. Another significant concern for various companies involves forecasting tire conditions, which can lead to accidents if overlooked. Currently, they assess tire lifespan manually, risking errors and requiring significant effort. These problems highlight the need for a comprehensive solution that addresses multiple aspects of fleet management and security. To address these issues, we propose developing an innovative fleet management software application. This upcoming system aims to: 1. Enable Real-Time Localization of Trucks: By implementing GPS tracking and real-time data analytics, the system will provide continuous monitoring of truck locations across countries. This feature aims to reduce the number of untraceable vehicle thefts by ensuring that trucks can be located at all times.

2. Detect Fuel Levels and Prevent Fuel Theft: The system will utilize sensors (ultrasonic), GPS modules, and GSM modules to monitor fuel levels and provide high-speed alerts and location data. This will help in detecting and preventing fuel theft, a significant issue faced by AVCO and many other companies.

3. Predictive Maintenance for Tires: To address the concern of tire condition forecasting, the system will include predictive maintenance capabilities. This feature will use data analytics to predict tire lifespan and maintenance needs, reducing the risk of accidents due to tire failure and minimizing manual assessment errors.

4. Comprehensive Logistics Management: The system will integrate these features with overall logistics management within AVCO. This integration will streamline operations, improve efficiency, and enhance the company's ability to manage its fleet effectively.

By addressing these specific challenges, the proposed system has the potential to significantly improve AVCO's operational efficiency and security. The real-time localization feature will ensure that missing trucks can be tracked and recovered quickly, reducing the motivation for

theft. The fuel monitoring system will help in detecting and preventing fuel theft, leading to substantial cost savings. The predictive maintenance feature will enhance safety and reduce the effort required for manual tire assessments. This innovative fleet management solution represents a significant step towards technological advancement in the transportation sector. For AVCO Investments Ltd, it offers a comprehensive approach to addressing longstanding security and efficiency concerns, potentially providing a competitive advantage in the market. The development and implementation of this system are expected to contribute to the broader effort to combat cargo theft and transportation insecurity, benefiting not only AVCO but the entire logistics industry.

2. Literature Review

To inform our research on developing an innovative fleet management system for AVCO Investments Ltd, we conducted a comprehensive review of existing literature. This review aims to identify current technologies, methodologies, and challenges in fleet management, with a particular focus on vehicle tracking, fuel monitoring, and tire condition forecasting.

2.1. Methodology

We employed a systematic literature search using databases such as IEEE Xplore, Elsevier's ScienceDirect, Google Scholar, and ACM Digital Library. The search terms included combinations of keywords such as "fleet management," "vehicle tracking," "fuel monitoring," "tire condition prediction," and "transportation security." We focused on peer-reviewed articles published within the last ten years to ensure relevance to current technological capabilities.

Overview of Relevant Studies

Our literature review revealed several key themes and technologies relevant to our project. Here, we summarize the most pertinent findings:

1. Vehicle Tracking and Fleet Management Systems

(Saeed et al., 2017) developed a bus tracking and fuel monitoring system using Arduino, GSM/GPS, and ASP.MVC technologies. Their system provided real-time bus arrival information and tracked bus locations on Google Maps. While effective, the system faced limitations in scalability and potential connectivity issues with GSM/GPS technology.

2. Fuel Monitoring Technologies

(Daniel Obikoya, 2014) presented a remote fuel-level monitoring system using a custom-designed fuel-level sensor and an Aplicom 12 GSM module. This system allowed for real-time querying of fuel tank volume information via mobile phone. However, the study did not address potential security concerns or integration with broader fleet management systems.

3. Tire Condition Monitoring and Prediction

(Kubba & Jiang, 2014) reviewed advancements in Tire Pressure Monitoring Systems (TPMS) and evaluated energy harvesting methods for tire condition monitoring. Their work highlighted the potential for battery-less monitoring solutions but lacked depth in practical implementation and economic analysis.

(Huang et al., 2015) developed a theoretical model for predicting three-dimensional global tire wear patterns based on factors such as road roughness, camber angles, and vehicle dynamics. While promising, this model requires experimental validation and may not account for all real-world complexities.

4. Noise and Vibration Analysis for Vehicle Health

(O'Boy & Dowling, 2009) used Finite Element modelling to analyze tire vibrations during road interaction, estimating noise levels over various road profiles. Their work contributes to the development of quieter tires and road surfaces but may not fully capture all dynamic factors in real-world conditions.

(Cesbron et al., 2009) explored tire-road interactions using in situ measurements, revealing correlations between contact forces and noise levels. Their findings, while valuable, were limited to specific speeds and road surfaces.

2.2. Gaps in Existing Research

Our review identified several gaps in the existing literature:

1. Limited integration of multiple fleet management functions (tracking, fuel monitoring, tire condition prediction) into a single, comprehensive system.

2. Insufficient attention to the specific challenges faced by transportation companies in Africa, particularly regarding cross-border operations and security concerns.

3. Lack of studies on the implementation of facial recognition technology in fleet management for driver authentication and security.

4. Limited research on the economic implications and return on investment for comprehensive fleet management systems in developing markets. While existing research provides valuable insights into various aspects of fleet management and vehicle monitoring, there is a clear need for an integrated solution that addresses the specific challenges faced by companies like AVCO Investments Ltd. Our proposed system aims to fill these gaps by combining real-time vehicle tracking, fuel monitoring, tire condition prediction, and driver authentication into a single, comprehensive platform tailored for the African market.

3. Proposed Solution

In response to the growing challenges faced by transportation companies in Africa, AVCO Investments Ltd is developing an innovative fleet management system. This comprehensive solution aims to address key issues such as cargo theft, fuel pilferage, and inefficient cross-border logistics. At the heart of the system is real-time vehicle tracking, utilizing GPS technology to provide accurate location data and route optimization. Studies have shown that similar systems can reduce travel times by up to 15% (Saeed et al., n.d.). This feature is particularly crucial for AVCO's cross-border operations, where timely information can significantly impact efficiency. Fuel theft, a persistent problem in the region, is tackled through advanced monitoring technology. Ultrasonic sensors and GSM modules will continuously track fuel levels, potentially reducing theft incidents by 30% (Daniel Obikoya, 2014). This not only protects assets but also provides valuable data for optimizing fuel consumption. Driver authentication adds an extra layer of security, employing facial recognition technology to

ensure only authorized personnel operate the vehicles. While still an emerging technology in this context, similar systems have shown promise in reducing unauthorized vehicle use by up to 90% (Huang et al., 2015). Tire condition prediction, based on the work of (Kubba & Jiang, 2014), is another key feature. By analyzing tire pressure, temperature, and vehicle dynamics data, the system can predict wear and potential failures. This proactive approach could extend tire life by 20% and reduce tire-related downtime by 30%. Perhaps most significantly for AVCO's operations, the system includes specialized features for cross-border logistics management. Drawing on insights from global transport systems research (Rodrigue, 2020), the platform aims to streamline border processes and optimize routes, potentially reducing cross-border transit times by 25%. While these features offer substantial benefits, their success will depend on effective implementation and user adoption. AVCO must also navigate the complexities of data privacy and security, especially concerning driver biometric data. As African logistics continue to evolve, AVCO's innovative system represents a significant step towards more efficient, secure, and competitive transportation operations. By addressing longstanding industry challenges with cutting-edge technology, AVCO is positioning itself at the forefront of logistics innovation in Africa.

3.1. System Operation

AVCO Investment Ltd is developing an integrated fleet management system to address the challenges of cross-border transportation. This system combines several technologies to improve operational efficiency, enhance security, and reduce incidents of theft and fraud.

Here's how the system works:

Real-Time Tracking and Monitoring: The system utilizes GPS technology to provide continuous, real-time location data for each truck in AVCO's fleet. This allows for precise tracking of vehicles as they cross international borders, enabling quick responses to unexpected delays or route changes.

Driver Authentication: Facial recognition technology is integrated into the system to verify driver identity. When a driver change occurs, the system automatically alerts management, reducing the risk of unauthorized vehicle use. This feature addresses a significant security concern in cross-border operations.

Tire Condition Assessment: The system incorporates image recognition technology to analyze tire conditions. Drivers can upload photos of tires, which are then processed by AI algorithms to assess wear patterns and potential issues. This automated approach reduces the need for manual inspections and helps prevent tire-related accidents. Inventory Management: An integrated inventory management module tracks cargo in real-time. Using RFID tags or similar technology, the system maintains an accurate count of items loaded and unloaded, minimizing manual errors in stock management.

Automated Reporting: The system generates automated reports on various aspects of fleet operations, including fuel consumption, route efficiency, and maintenance needs. This reduces the reliance on manual data entry and provides management with timely, accurate information for decision-making. While this system offers significant potential benefits, its effectiveness will depend on proper implementation and user adoption. Privacy concerns, particularly regarding facial recognition technology, will need to be carefully addressed. Additionally, the system's reliance on various technologies may present challenges in areas with limited connectivity. As AVCO Investment Ltd moves forward with this system, careful evaluation of

its performance in real-world conditions will be crucial. The company will need to balance the potential efficiency gains with the costs of implementation and ongoing maintenance. If successful, this integrated approach could serve as a model for other companies facing similar challenges in cross-border transportation.

4. Conclusion And Future Work

AVCO Investments Ltd is set to introduce a groundbreaking fleet management system, designed to address the unique challenges faced by transportation companies operating across African borders. This comprehensive solution aims to transform how logistics firms manage their operations, from warehouse planning to real-time vehicle tracking. At the heart of the new AVCO Management System is a suite of tools focused on improving warehouse efficiency and stock management. By leveraging advanced analytics and forecasting algorithms, the system will enable more accurate planning for trailer and truck utilization, potentially reducing idle time and maximizing asset productivity. A key feature of the system is its ability to streamline trip sheet expense management. This functionality is expected to significantly reduce administrative overhead and provide managers with real-time insights into operational costs. Additionally, the system will generate a variety of customizable reports, offering decision-makers a comprehensive view of their operations at any given time. Tire management, a critical aspect of fleet maintenance, receives special attention in the AVCO system. By tracking tire wear and predicting replacement needs, the system aims to reduce unexpected downtime and extend the lifespan of these crucial components. Customer management features are integrated into the platform, allowing for improved communication and service delivery. By providing real-time updates on shipment status and estimated arrival times, AVCO expects to enhance customer satisfaction and loyalty. One of the primary goals of the system is to reduce overall expenses for transportation companies. By optimizing routes, improving maintenance scheduling, and providing better oversight of fuel consumption, the AVCO Management System has the potential to significantly impact a company's bottom line. Looking to the future, AVCO plans to expand the system's capabilities. A mobile app is in development, which will allow managers to access critical information and make decisions on-the-go. Additionally, a client web portal is planned, enabling customers to track their shipments in real-time and make automated payments. The wealth of data collected by the system opens up possibilities for advanced financial forecasting. AVCO envisions integrating predictive analytics to help companies make more informed long-term business decisions. While the system shows great promise, it's important to note that successful implementation will require careful planning and user training. Companies considering adoption should assess their specific needs and ensure they have the necessary infrastructure to support such a comprehensive system. As African logistics continue to evolve, solutions like the AVCO Management System represent a significant step forward. By addressing the unique challenges of cross-border transportation and leveraging cutting-edge technology, AVCO is positioning itself as a leader in the modernization of African logistics.

5. Acknowledgment

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Framework for Artificial Intelligence in Education: Resource Management for Sustainable Future

L. Judith
The Nelson Mandela African Institution of Science and Technology, (NM-AIST), Arusha, Tanzania.

Abstract: Over the last decade, Artificial intelligence (AI) has become increasingly important and has shown a significant impact in various sectors, including the education sector. There is a considerable amount of research on AI applications for education, such as innovative and adaptive teaching and learning, leading to accelerated progress toward SDG 4. However, it has been observed that the rapid development of AI in the education sector inevitably brings multiple risks and challenges such as limited resources including human capital, infrastructure, and ethical concerns. In response to these multiple risks and challenges, this study reviewed existing literature and conducted a study survey and focus group discussion to guide the development of an AI framework in the education sector for African countries. Based on the findings, the framework should have five key dimensions which include knowledge transfer and capacity building, data management, resource allocation and centralization, content development, and ethics and responsible use. These five key dimensions should be guided by the integration of equity, inclusivity, and a sense of regular monitoring, evaluation, and continuous improvement. Lastly, the study recommends regular monitoring, evaluation, and continuous improvement of the frameworks, policies, and guidelines related to AI following its pace of revolution and development.

Keywords: Artificial Intelligence, Framework, Education, Resource Management, Sustainability.

1. Background Introduction

Artificial intelligence (AI) has become increasingly important in recent years and has shown significant impact in various sectors, including healthcare, finance, mining, and agriculture (van Buren et al., 2020). The education sector is no exception and there is a considerable amount of research in the use and development of AI applications for education, such as promoting personalization of learning as it allows adapting study materials to the level of each student; administrative efficiency by automating administrative tasks hence allowing educators to focus more on teaching; facilitate accessibility to high-quality education resources regardless of economic status or geographical location; provide continuous assessment as it can assess each student's progress and provide real-time feedback as well as adaptive teaching and learning, leading to acceleration progress towards sustainable development goal (SDG) 4 (Ahmad et al., 2020; Demaidi, 2023; Kuleto et al., 2021; Sinde et al., 2023). In Africa, AI is being integrated into the educational landscape, but the pace remains very low, with the use of AI uncommon at lower educational levels and rapid adoption at higher learning institutions, where solutions such as AI-powered chatbots are increasingly becoming popular (Gwagwa et al., 2020; ITU & UNDP, 2023; Sedola et al., 2021). According to the literature, it has been observed that the rapid development of AI in the education sector inevitably brings multiple risks and challenges such as limited resources including

human capital, infrastructure, and ethical concerns. The ethical concerns include privacy violations, algorithmic bias, and safety concerns.

In response to the rapid use and development of AI applications, the majority of African countries under the capacities of governments, organizations, and institutions are drafting, developing, or adopting AI strategies and policies to guide its effective implementation for sustainable economic development of their countries. African nations such as Tunisia, Egypt, and Nigeria have made the initial moves to establish governance and policy frameworks to direct the development and application of AI while other nations are still lagging (Heumann et al., 2018; Sinde et al., 2023; UNESCO, 2022). With this motive, this paper aims to review existing literature on different AI frameworks, guidelines, and policies with a focus on the education sector at national, regional, and international levels and then develop a framework for AI in education that will guide effective resource Management for sustainable development of Africa. This paper consists of four sections which include introduction, methodology, results and discussion, and lastly, recommendations and conclusion.

2. Methodology

The methodology of this study deployed both qualitative and quantitative research methods with the utilization of proprietary vocabulary to discover and extract quality information from the literature and identified stakeholders including policymakers, Government institutions, community service, and public sectors, as well as other related stakeholders using a snowballing approach. Throughout the process, iterative methods were used in each stage to review and incorporate missing and new required information and also, examine thoroughly the received and collected valuable insights, leading to serve as a resource to inform and provide actionable recommendations that guide the development of the proposed framework. The collected data was cleaned and annotated using tools such as Python and Excel, then, analyzed, synthesized, and documented using tools such as PowerBI, Python, DAX, and Tableau. The following Figure 1 briefly describes the methodology used in this study.

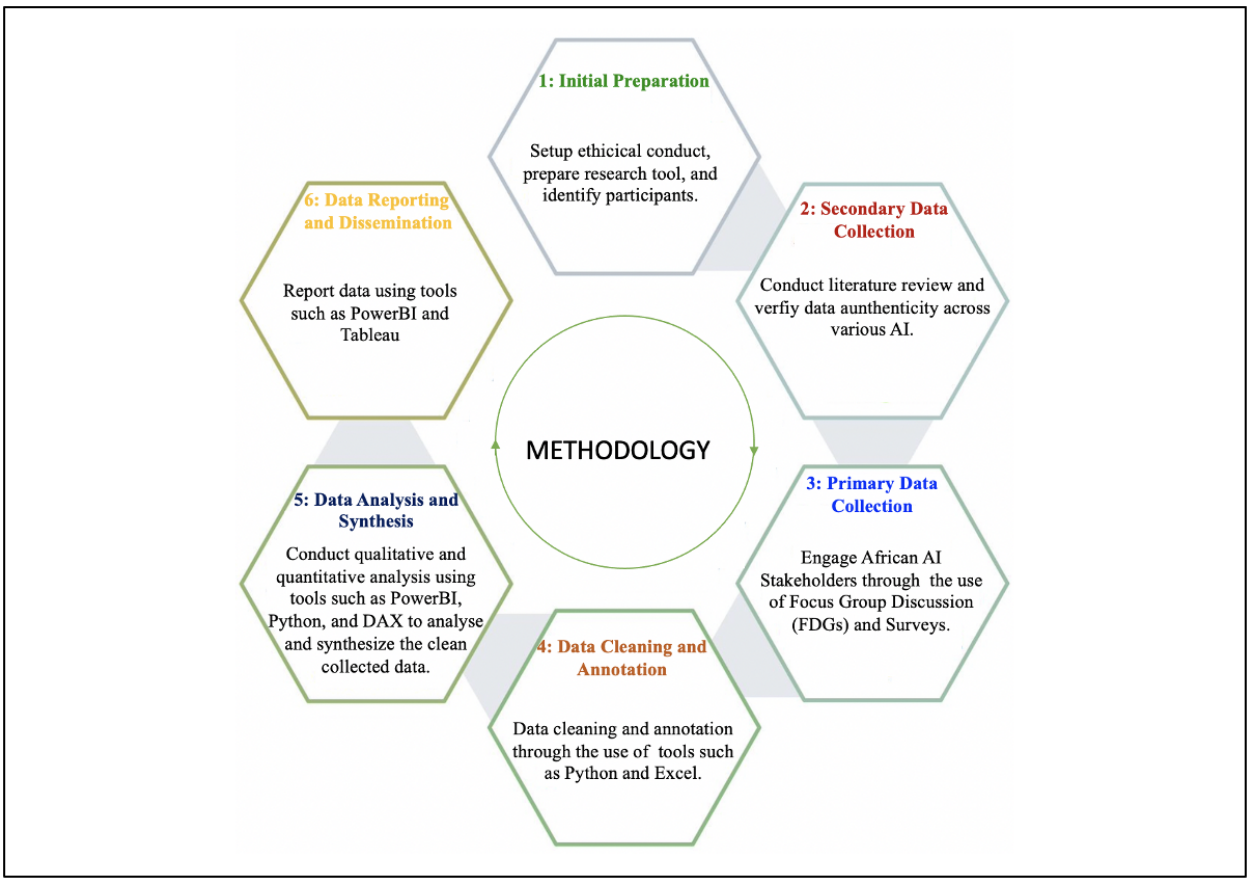

Fig. 1: Steps used in the study methodology.

3. Results and Discussion

3.1. Results from the Literature Review

Based on the understanding of the current status of existing AI frameworks, strategies, and policies, it was observed that there are several efforts that have been made so far in the continent. These efforts include the revised implication of emerging technologies which was conducted by the African Development Bank in 2018 and the need for assurance fort he use and development of AI, robots and other emerging technologies applications are compatible with the human rights principles and enhance job creation opportunities in various development sectors including education as noted by the African Commission on Human and Peoples' Rights (ACHPR), UNESCO, and the African Union Development Agency (AUDA-NEPAD). Due to these initiatives, other African countries have gone ahead towards developing AI strategies, policy drafts, and published policies and some have already started implementing them (Akello, 2022; Brief, 2023; Law, 2023; UNESCO, 2014, 2022). The countries including Mauritius, Egypt, Benin, and Senegal have developed AI strategies in 2018, 2021, and 2023 respectively, Tanzania and Nigeria's Governments have announced to start drafting their Nationa AI Strategies (Adams, 2022; George, 2017). Whereas Rwanda (2023) has already developed and published an AI policy to serve as a roadmap toward harnessing the benefits of AI and mitigating its risks (Ministry of Information Technology and Communications, 2019; The African Development Bank, 2021; Tikoudi, 2023; World Bank, 2020). However, there are no AI frameworks that have been developed so far in African countries to cater only to the needs

of the education sector. Therefore, currently, most oft he African countries are referring to foreign AI frameworks, guidelines, and policies from countries like China-Beijing and the Kingdom of Saudi Arabia to guide the use of tools such as ChatGPT in the education sector.

3.2. Results from the Respondents

The total number of respondents who participated in the online survey and focus group discussion (FDG) was 132, whereby 43% of them were female. The participants were described into four groups of AI stakeholders which included Academia (40%), Firms (30%), Government (25%), and Civil Society (5%) and all of them were African either living in African countries or outside the African continent. Additionally, 55% of participants were aged 25-35 years, 22% were aged 18-24 years, 13% were aged 35-44 years, 8% were aged 45-54 years, and 2% were aged 55 years and above. Based on their responses, the following challenges were identified to hinder the successful adoption, use, development, deployment, and implementation of AI technology in the education sector in African countries. These challenges include, knowledge transfer and capacity building (19%), data management (18%), resource allocation and centralization (20%), content development (19%), and ethics and responsible use (24%) were identified as the key dimensions to consider in the framework of AI in the education sector in Africa. Fig. 2 briefly describes the demographic and response results from the analyzed collected data.

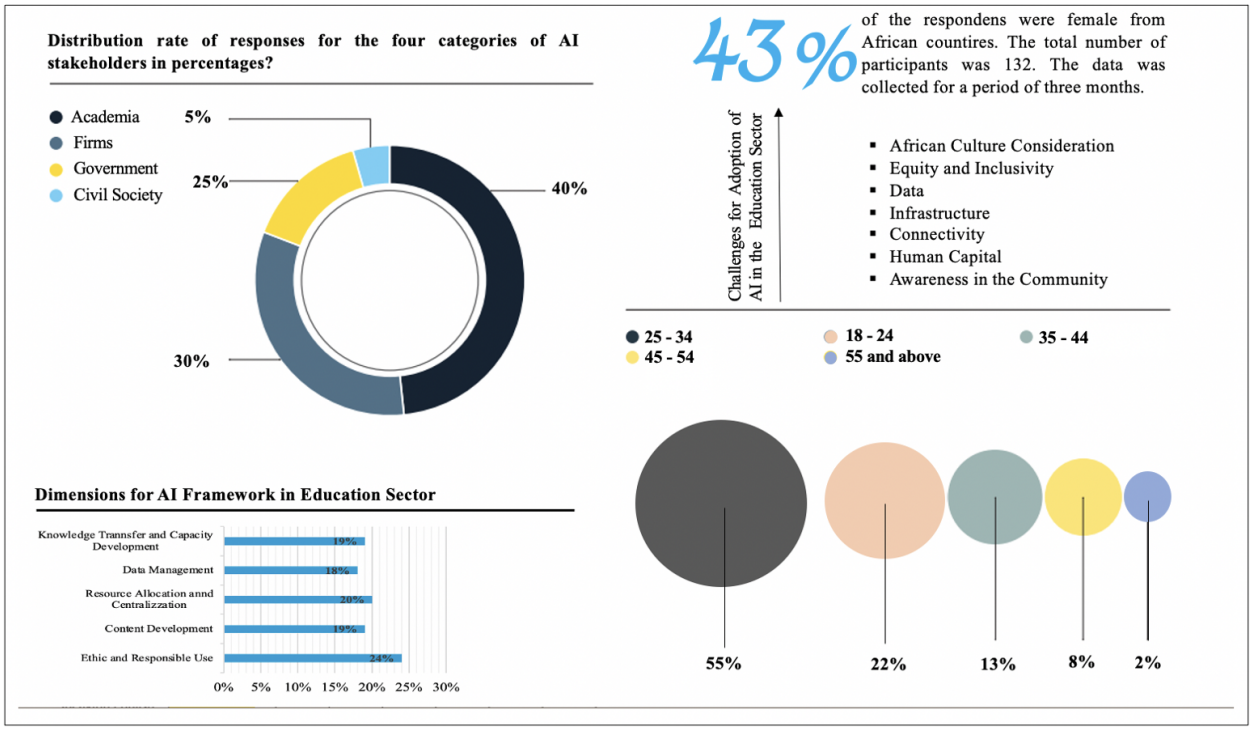

Fig. 2 Demographic and Respondent Results.

3.3. Discussion

Artificial Intelligence is the foundation of digital transformation and innovation of Africa, leading the new stage of advancing society and industry that affects the future of Africa (Sedola et al., 2021; Sinde et al., 2023; van Buren et al., 2020). With the wide adoption and use of AI technology in the education sector, there is a need to put measures and strategies that will stakeholders and institutions in the education sector for the sustainable social economic

development of Africa and the world at large. Therefore, based of the findings the following is the proposed framework for AI in the education sector in African countries. The framework has five key dimensions which include (i) knowledge transfer and capacity building, (ii) data management, (iii) resource allocation and centralization, (iv) content development, and (v) ethics and responsible use. These frameworks are guided by the integration of equity, inclusivity, and a sense of regular monitoring, evaluation, and continuous improvement. Fig. 3 briefly details the framework of AI in the education sector in African countries.

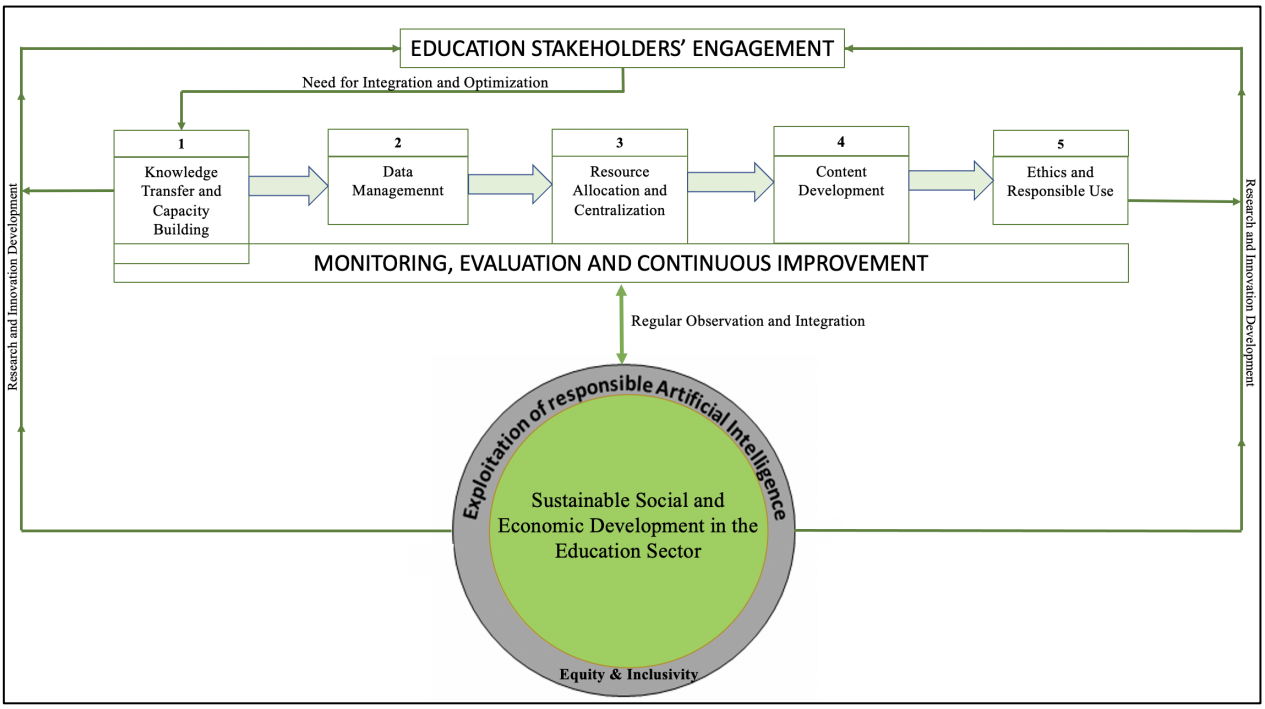

Fig. 3 Framework of AI in Education Sector in African.

4. Conclusion and Recommendation

Education is significant in our lives, whereby teaching and learning are its main features (Abdulkadir & Zainuddin, 2018). According to the findings, education increases the power of visualization and differentiation between right and wrong. Additionally, nowadays it has been observed that the future of education is directly related to innovative tools and computing abilities of intelligent machines through the use of emerging technologies such as AI, leading to the opening of new potentials and tasks for teaching and learning in education (Ahmad et al., 2020; Munir et al., 2022; The Secretary of State, 2016). Therefore, the proposed framework for AI in education in this study has five key dimensions which include (i) knowledge transfer and capacity building, (ii) data management, (iii) resource allocation and centralization, (iv) content development, (v) ethics and responsible use. The framework focused on the integration of key principles of equity and inclusivity with regular monitoring and evaluation to achieve responsible exploitation of AI in the education sector for sustainable development. The study recommends regular monitoring, evaluation, and continuous improvement of the frameworks, policies, and guidelines related to AI following its pace of revolution and development.

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