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CONTENT

FOREWORD

The 6th issue of the Bavarian Journal of Applied Sciences (BJAS) is also a relaunch of the journal after a two-year break due to the COVID-19 pandemic.

In the meantime, the editorial team has grown with the addition of Michelle Cummings-Koether, Professor of Intercultural Management at the European Campus Rottal-Inn (ECRI). Together with her, the journal's quality assurance criteria as well as the review and publication process have been further developed and refined. The BJAS remains the publication medium for young researchers, enabling them to publish their research results according to a standardized, double-blind peer review process. At least one of the two reviews is provided by non-DIT academics while the second review is usually done by DIT academics.

The articles published here cover a wide range of topics.

The first article is by Zineddine Bettouche and Andreas Fischer (DIT). Using machine learning methods, the two computer scientists created a thematic map of research activities based on the publications of DIT researchers. By coding and clustering research publications, they created a map representation of research-active scientific fields. Similarities and differences between researchers became evident, which in turn revealed the potential for joint research work.

Physicist Jens Ebbecke (DIT) investigated the influence of the electromagnetic beat signal method on biological systems. In a first test, garden cress was exposed to low-frequency electromagnetic waves over a certain period of time to influence its germination and initial growth. The results can be used for similar experiments in other areas, such as influencing the growth of bacteria or even human cells.

Maike Netscher, Thomas Rehrl, Stephanie Jordan, Mara Roschmann, Daniela Seibel, Katharina Kill, Pearl Heppler, Marc Lunkenheimer and Alexander Kracklauer (Neu-Ulm University of Applied Sciences) have investigated the acceptance of product configurators in a quantitative study using the cosmetics industry as an example and have highlighted the variables that are decisive for their acceptance.

Lukas Schmidbauer (DIT) also dealt with acceptance, however, in the field of nursing sciences. Exoskeletons were developed to make physical work easier for nursing staff. The article reports on a case study dealing with the acceptance of these exoskeletons. According to the study, insufficient information about the benefits of exoskeletons is one reason why the acceptance of their benefits in nursing is still very low.

Finally, Helana Lutfi, Rui Li and Thomas Spittler (DIT) report on a study conducted at DIT‘s European Campus Rottal-Inn on the planning and implementation of online teaching and how it can be successfully realized.

We as principal editors would like to thank the reviewers for their highly important contributions to improving the quality of the journal. We also thank Esther Kinateder for the excellent proofreading work and Sandra Maier for doing a great job in typesetting this issue.

Michelle Cummings-Koether & Kristin Seffer

Die 6. Ausgabe des Bavarian Journal of Applied Sciences (BJAS) ist gleichzeitig ein Neustart des Journals nach einer zweijährigen Corona-bedingten Pause.

In der Zwischenzeit ist das Editorial Team um Michelle Cummings-Koether, Professorin für Intercultural Management am European Campus Rottal-Inn (ECRI), gewachsen. Gemeinsam mit ihr wurden die Qualitätssicherungskriterien des Journals sowie der Begutachtungs- und Publikationsprozess weiterentwickelt und verfeinert. Das BJAS bleibt das Publikationsmedium für Nachwuchswissenschaftler:innen, das diesen ermöglichen soll, ihre Forschungsergebnisse nach einem standardisierten, Double-Blind-Peer-Review-Verfahren zu veröffentlichen. Mindestens eines der beiden Gutachten wird von Wissenschaftler:innen, die nicht der THD angehören, und das zweite Gutachten üblicherweise von Angehörigen der THD erstellt.

Die hier veröffentlichen Beiträge decken eine breite Bandbreite an Themen ab.

Den Auftakt bildet ein Artikel von Zineddine Bettouche und Andreas Fischer (THD). Die beiden Informatiker erstellten mithilfe von Methoden des Maschinellen Lernens aus den Publikationen der Angehörigen der THD eine Themenlandkarte ihrer Forschungsaktivitäten. Durch Kodierung und Clusterung von Forschungspublikationen erarbeiteten sie eine Kartendarstellung forschungsaktiver Wissenschaftsfelder. Es kristallisierten sich Ähnlichkeiten und Unterschiede zwischen Forschenden heraus, die wiederum das Potenzial für gemeinsame Forschungsarbeiten aufzeigen.

Der Physiker Jens Ebbecke (THD) untersuchte den Einfluss der Methode der elektromagnetischen Schwebung auf biologische Systeme. In einem ersten Test wurde Gartenkresse über einen bestimmten Zeitraum mit niederfrequenten elektromagnetischen Wellen bestrahlt, um deren Keimung und das initiale Wachstum zu beeinflussen. Die Ergebnisse können für ähnliche Versuche in anderen Bereichen, wie der Beeinflussung des Wachstums von Bakterien oder auch menschlicher Zellen herangezogen werden.

Maike Netscher, Thomas Rehrl, Stephanie Jordan, Mara Roschmann, Daniela Seibel, Katharina Kill, Pearl Heppler, Marc Lunkenheimer, Alexander Kracklauer (Hochschule Neu-Ulm) haben in einer quantitativen Studie die Akzeptanz von Produktkonfiguratoren am Beispiel der Kosmetikindustrie untersucht und die Variablen herausgestellt, die für deren Akzeptanz entscheidend sind.

Um Akzeptanz geht es auch bei Lukas Schmidbauer (THD) im Bereich der Pflegewissenschaften. Exoskelette wurden entwickelt, um die körperliche Arbeit für Pflegekräfte zu erleichtern. Der Beitrag berichtet über eine Fallstudie zur Akzeptanz von Exoskeletten. Demnach seien unzureichende Informationen über den Nutzen von Exoskeletten ein Grund dafür, dass die Akzeptanz für deren Benefits in der Pflege noch sehr gering ausfällt.

Helana Lutfi, Rui Li und Thomas Spittler (THD) berichten schließlich über eine am European Campus Rottal-Inn der THD durchgeführte Studie zur Planung und Umsetzung von Online-Unterricht und wie dieser erfolgreich realisiert werden kann.

Die Herausgeberinnen danken den Gutachterinnen und Gutachtern, deren Beitrag zur Sicherung der Qualität des Journals kaum hoch genug geschätzt werden kann. Ein großes Dankeschön an Esther Kinateder für das sorgfältige Korrektorat und an Sandra Maier ihre hervorragende Arbeit beim Satz und ihre Geduld.

Michelle Cummings-Koether & Kristin Seffer

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Topical Clustering of Unlabeled Transformer-Encoded Researcher Activity

Zineddine Bettouche* **Andreas Fischer***

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ABSTRACT

Transformer models have the ability to understand the meaning of text efficiently through the use of self-attention mechanisms. We investigate the bundled meanings in clusters of transformer-generated embeddings by evaluating the topical clustering accuracy of the unlabeled scientific papers of the DIT publications database. After experimenting with SciBERT and German-BERT, we focus on mBERT as we work with multilingual papers. We create a landscape representation of the scientific fields with active research through the encoding and clustering of research publications. With the absence of topic labels in the data (no ground truth), the clustering metrics cannot evaluate the accuracy of the topical clustering. Therefore, we make use of the coauthorship aspect in the papers to perform a coauthorship analysis in two parts: the investigation of the authors' uniqueness in each cluster and the construction of coauthorship-based social networks. The calculated high uniqueness of authors in the formed clusters and the found homogeneity of topics across the connected components (in social networks) imply an accurate topical clustering of our encodings. Moreover, the constructed social networks indicate the existence of a set of connecting internal authors, whose collaborations with each other formed a large network, holding 74% of all papers in the database.

Transformer-Modelle haben die Fähigkeit, die Bedeutung von Texten mithilfe von Self-Attention-Mechanismen effizient zu verstehen. Wir untersuchen die semantische Bedeutung von Clustern, welche sich aus den durch die Transformer generierten Embeddings ergeben. Dabei wird die Treffsicherheit der thematischen Zuordnung ungelabelter wissenschaftlicher Publikationen aus der THD-Publikationsdatenbank bewertet. Nachdem wir mit SciBERT und German-BERT experimentiert haben, konzentrieren wir uns bei der Arbeit mit mehrsprachigen Artikeln auf mBERT. Die dargestellten Cluster der wissenschaftlichen Publikationen ergeben eine durchsuchbare Forschungslandschaft aller mittels Publikationen aktiven Disziplinen der THD. Da in den Daten keine Themenbezeichnungen vorhanden sind (keine Grundwahrheit), können die Clustering-Metriken die Genauigkeit des thematischen Clusterings nicht bewerten. Daher nutzen wir den Aspekt der Koautorenschaft in den Arbeiten, um eine Koautorenschaftsanalyse in zwei Teilen durchzuführen: der Untersuchung der Einzigartigkeit der Autorinnen und Autoren in jedem Cluster und dem Aufbau koautorenschaftsbasierter sozialer Netzwerke. Die berechnete hohe Einzigartigkeit der Autorinnen und Autoren in den gebildeten Clustern und die gefundene Homogenität der Themen über die verbundenen Komponenten (in sozialen Netzwerken) implizieren eine genaue thematische Clusterung unserer Kodierungen. Darüber hinaus weisen die konstruierten sozialen Netzwerke auf die Existenz einer Reihe miteinander verbundener interner Autorinnen und Autoren hin, deren Zusammenarbeit untereinander ein großes Netzwerk bildete, das 74 % aller Beiträge in der Datenbank enthält.

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KEYWORDS

Topical clustering, document similarity, document encoding, BERT, natural language processing, clustering, k-means, DBSCAN, keyword extraction

Thematische Gruppierung, Ähnlichkeit von Dokumenten, Kodierung von Dokumenten, BERT, Computerlinguistik, Clusteranalyse, k-Means, DBSCAN, Schlagwortextraktion

1. Introduction

In recent years, the development of transformer models, such as the Bidirectional Encoder Representations from Transformers (BERT) model or the GPT series responsible for the popular ChatGPT, has revolutionized the field of natural language processing (NLP). These models have achieved stateof-the-art performance on various NLP tasks, including text classification, sentiment analysis, and question-answering.

A key feature of transformer models is their ability to encode the meaning of text efficiently. This allows them to generate contextualized mappings into a multidimensional vector space (embeddings) for each sentence. These embeddings can then be used as input to downstream tasks, such as classification or prediction. A clustering of these vectors is expected to highlight groups of semantically similar publications.

The focus of this article is on the topical clustering of scientific papers in the publications database of the DIT. These papers are published on certain topics, and their transformergenerated encodings reflect their corresponding topics. The goal of the approach is to highlight topical clusters without deliberately labeled data. The topic of each paper is represented by the contextualized transformer-generated embedding (vector). We assume that clustering the paper vectors leads to clusters representing the collective topic of its papers. Our investigation tries to establish that the identified clusters reasonably reflect the active research areas (in terms of published research papers) at the DIT.

The main research questions answered in this paper are:

- Can a fully unsupervised approach provide topical clusters that are semantically coherent and useful to understand the research landscape?
- Regarding multilingual input (which is relevant at any non-English research institution), can a multilingual model such as mBERT perform on par with a specialized model such as SciBERT, while including non-English texts?

In our previous work [1], we established a methodology for calculating the cross-distance between a pair of authors based on the respective encodings of their papers. We utilize this methodology to investigate the topics in the clusters. Initially, we reintroduce the encoding of data using Base-BERT and SciBERT and focus on obtaining a direct distance between any given pair of authors. We also utilize German-trained BERT models to process and investigate the German papers in our data that were cast aside previously. To consolidate all papers into a single landscape, we then employ a multilingual BERT model (mBERT), which provides efficient encoding regardless of language while still offering reasonable clustering performance.

Since topical labels are not pre-assigned in the publications database, the quality of the obtained clusters is not straightforward to measure. Instead, quality is verified in two ways: Author cluster uniqueness and coauthor cluster consistency. A high number of unique authors per cluster, i.e., authors belonging to only that cluster, indicates that authors are clustered in a meaningful way. Investigating the co-author social networks, network size is expected to correlate strongly with the number of clusters covered. The experiments performed verify that assumption.

Surprisingly, we discovered that even in the comparatively small publications database of the DIT, a large connected component is found, covering about 3/4 of all publications.

Still, even in this large component, the topical clustering is clearly recognizable. The results of this paper therefore support the idea of an unsupervised approach for identifying topical clusters of research topics. This is the basis for drawing a comprehensive research landscape of publishing authors at the DIT.

As for the structure of this article, Section II presents the background of the technologies we use, such as transformer models, clustering techniques, and social networks. Section III discusses the previous works that dealt with BERT models, semantic similarity, and the clustering of transformer-generated encodings. Section IV is a data analysis section, in which we analyze the data we use in terms of textual property distributions (i.e., character and token count distributions). Section V presents the methodology of our work. It is similar to the methodology used in our previous paper [1]; however, we discuss the new angle, which we make use of to achieve our aim in this work. Section VI presents the experiments done in this work, their implementation and the rationale behind them. Finally, Section VII concludes the work and sets up possible future developments that could be built on our findings.

2. Background

This section introduces the applied techniques, in particular: transformers, clustering techniques, cluster evaluation metrics, keyword extraction, visualization of high-dimensional vector spaces, and social network analysis.

A. Transformers

Transformer models are a class of deep neural networks that have greatly advanced natural language processing (NLP) tasks in recent years. They were introduced in a landmark paper by Vaswani et al. [2]. Traditional NLP models, such as recurrent neural networks (RNNs) and convolutional neural networks (CNNs), have limitations in handling long-range dependencies and contextual information in a sentence or document. Transformer models overcome these limitations by using self-attention, a mechanism that allows the model to focus on the most relevant parts of the input text at each time step, while capturing long-range dependencies between words.

The transformer model consists of an encoder and a decoder, with self-attention as its key component. The encoder takes in the input text and encodes it into a sequence of hidden states, which are then used by the decoder to generate the output sequence. Self-attention is applied to each token in the input sequence to compute a weighted sum of all the tokens, with the weights determined by their similarity to the current token. This enables the model to attend to the most important parts of the input at each time step, while capturing longrange dependencies between words. Transformer models have achieved state-of-the-art performance on a wide range of NLP tasks, including language modeling, machine translation, and text generation, and are widely used in both academia and industry.

In our work, we use models of BERT [3] (Bidirectional Encoder Representations from Transformers) to encode our scientific papers, because they are capable of capturing semantic and contextual information in the text, which is crucial for understanding the research landscape of the papers. The encoded representations generated by transformer models are high-dimensional and dense, which can capture the complex relationships between the phrases in the papers. This makes the clustering process on the paper encodings likely to be dependent on the topics of these papers, which is what our paper attempts to investigate.

B. Clustering Techniques

K-means [4] and DBSCAN [5] are two widely used clustering algorithms in machine learning. K-means is a partitioning algorithm that works by dividing data into K clusters, where K is a pre-defined hyperparameter. The algorithm starts by randomly selecting K points from the data as the initial cluster centroids. It then assigns each point in the dataset to the nearest centroid and updates the centroids to be the mean of the points in the cluster. This process is repeated until the centroids no longer change, indicating convergence. K-means is widely used due to its simplicity, speed, and scalability. However, it has some limitations, including its sensitivity to the initial selection of centroids and the assumption that the data is globular.

DBSCAN, on the other hand, is a density-based clustering algorithm that works by grouping together points that are closely packed together in high-density regions, while also identifying

points that are outliers. The algorithm defines clusters as areas of high density separated by areas of low density. It starts by selecting a random point and finding all the points that are within a pre-defined distance epsilon of that point. It then expands the cluster by recursively finding all the points that are also within epsilon of those points, until the cluster reaches its maximum density. The algorithm then repeats this process for other points in the dataset, assigning them to existing clusters or marking them as outliers. DBSCAN is useful in identifying clusters of arbitrary shape and is less sensitive to the initial parameters than K-means. However, it can be computationally expensive and requires setting two hyperparameters, epsilon, and the minimum number of points required to form a cluster.

In this paper, we cluster the BERT encodings of the papers in our database with K-means and observe the topics of the formed clusters. Density-based clustering is set to be addressed in future work.

C. Cluster Evaluation Metrics

Evaluating the quality of research paper clusters is crucial to ensuring that the resulting clusters are meaningful and accurate. We use Silhouette [6], Calinski-Harabasz [7], and Davies-Bouldin [8] metrics to evaluate the quality of the clusters. Silhouette measures how well each data point fits into its assigned cluster compared to other clusters, while Calinski-Harabasz measures the ratio of between-cluster variance to within-cluster variance. Davies-Bouldin measures the average similarity between each cluster and its most similar cluster. These metrics provide a quantitative measure of the quality of the research paper clusters. We record these metrics as we describe the clustering results for future reference. However, as we work with unlabeled data, it is hard to evaluate the clusters with only these metrics. Therefore, we employ social networks built upon coauthorships.

D. Keyword Extraction with KeyBERT

KeyBERT [9] is a state-of-the-art keyword extraction algorithm that uses the transformer architecture to extract the most relevant words or phrases from a given piece of text. Specifically, KeyBERT fine-tunes a pre-trained transformer model, on a large corpus of text to create a keyword extraction model. The algorithm works by first embedding the input text using the pre-trained transformer model and then using a cosine similarity function to compare the embedding of each word or phrase in the text to the overall text embedding. The words or phrases with the highest similarity scores are selected as the most relevant keywords for the text. KeyBERT has several advantages over other keyword extraction algorithms, including its ability to capture the context and meaning of words and phrases, its flexibility in handling different types of text, and its speed and efficiency. In this paper, we use KeyBERT to extract keywords from the research papers in each cluster, which allowed us to explore the topics present in each cluster to assess the topical clustering of our data.

E. Visualization with UMAP

UMAP [10], or Uniform Manifold Approximation and Projection, is a powerful dimensionality reduction technique that has gained widespread popularity in recent years. UMAP works by constructing a low-dimensional representation of high-dimensional data such that the local structure of the data is preserved as much as possible. Specifically, UMAP constructs a topological representation of the data using a fuzzy simplicial set, which captures the local relationships between points in the high-dimensional space. It then constructs a low-dimensional embedding of the data using a nonlinear optimization algorithm that preserves these relationships to the highest possible extent. The optimization process is guided by a loss function that balances the preservation of local structure with the need to spread out points in lowdimensional space. UMAP has several advantages over other dimensionality reduction techniques, including its ability to preserve both local and global structure, its ability to handle non-linear relationships between variables, and its speed and scalability for large datasets. In this paper, we use UMAP to visualize the clusters formed by our clustering methodology, providing a powerful tool for exploring the relationships between different research papers and their authors.

F. Social Networks

Social networks are a valuable resource for understanding the relationships and collaborations between individuals in a particular field of study. The *networkx* library [11] in Python provides an efficient and easy-

to-use tool for constructing and analyzing social networks. The library allows researchers to create graphs and networks, where nodes represent individuals and edges represent relationships between them. By analyzing the structure of these networks, researchers can gain insights into the patterns of collaboration and knowledge transfer in their field of study. In this paper, we use *networkx* to construct coauthorship networks, which provided us with a unique perspective on the relationships between authors in different research paper clusters. This analysis allowed us to identify authors who were unique to each cluster, providing further evidence for the topic-based nature of our clustering methodology.

3. Related Work

The use of transformer models for encoding and clustering scientific data has gained considerable attention in recent years. Guo et al. [12] presented an unsupervised clustering method for grouping scientific articles into meaningful clusters based on the encodings generated by transformer models. However, their data was not multilingual, and their work did not include density-based clustering. Similarly, Beltagy et al. [13] introduced SciBERT, a pre-trained transformer model that is specifically designed for scientific text. SciBERT is trained on a large corpus of scientific documents and has been shown to outperform general purpose language models in various downstream tasks such as named entity recognition and relation extraction. Multilingual clustering is another area where transformer models have been applied. In a paper by Artetxe et al. [14] a method was presented for unsupervised multilingual representation learning that can be used for clustering low-resource languages. Their method leverages cross-lingual encodings generated by transformer models to group similar words and phrases across different languages. This approach has the potential to significantly reduce the amount of labeled data required for clustering low-resource languages.

Concerning semantic similarity, Ostendorff et al. [15] found that SciBERT outperformed other models in measuring aspectbased document similarity. Chandrasekaran and Mago [16] noted that recent hybrid methods show promise in measuring semantic similarity. Kades et al. [17] developed methods to address semantic similarity in medical data using BERT. Yang et al. [18] demonstrated the use of transformer-based models in measuring semantic similarity in clinical texts and found that RoBERTa performed the best.

Social network analysis has also been a popular topic in the field of scientific research. Coauthorship networks, in particular, have received much attention due to their ability to reveal patterns of collaboration and knowledge exchange among researchers. In a paper, Newman et al. [19] provided an overview of coauthorship networks and their applications in different fields, including bibliometrics, sociology, and computer science. Meanwhile, Ravasz et al. [20] proposed a method for detecting overlapping and hierarchical community structures in networks. This method


```
{
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    ]
}
```


Figure 1. Paper-Object Example

uses a combination of density-based clustering and hierarchical clustering to identify groups of nodes that are tightly connected to each other.

Density-based clustering algorithms have also been proposed for high-dimensional vectors, such as the DBSCAN algorithm introduced by Ester et al. [5]. DBSCAN is particularly effective at identifying clusters of varying shapes and sizes, which makes it a suitable algorithm for clustering highdimensional data such as transformer encodings. On the other hand, centroid-based clustering algorithms, such as K-means, have been widely used in clustering high-dimensional vectors. Bahmani et al. [21] proposed a scalable version of the Kmeans algorithm that is capable of clustering massive datasets efficiently.

Overall, these studies demonstrate the potential of using transformer models for encoding and clustering scientific data, as well as the importance of considering social networks and density-based clustering algorithms in this context. By leveraging the latest advances in machine learning, we can generate clusters of the BERT encodings of our research papers, and perform a topic-based evaluation by means of coauthorship-based social networks.

4. Exploratory Data Analysis

This paper uses the same data as our first results paper [1], consisting of 7,548 references. The data include various types of references, but only 1,500 (sic) scientific articles with abstracts are chosen for this investigation. Each selected entry has at least a title, a list of authors, a date, and an abstract, topically unlabeled. An example of an entry is shown in Figure 1, where authors are marked by name and internal authors are identified by their e-mail addresses. We remove entries that have over 512 tokens in their abstract. The BERT models have a limitation of 512 tokens per input (with the exception of SciBERT, which is limited to 768 tokens). If a text item has more tokens, the BERT model will truncate the input, which can result in the loss of valuable information. Figure 2 shows the histogram of the token count per abstract. After the removal of the items with no abstracts (presentations, interviews, etc.) and the items with an abstract token count over 512, we end up with 1,459 items. An overview is shown in Table I.

Selection criterion	Value
Total # publications	7,548
Publications w. abstracts	1,500
Abstracts < 512 tokens	1,459

Table 1: Summary values for the publications database

5. Methodology

This section presents the general processing approach implemented in this work and the methodology used to calculate the cross-distances

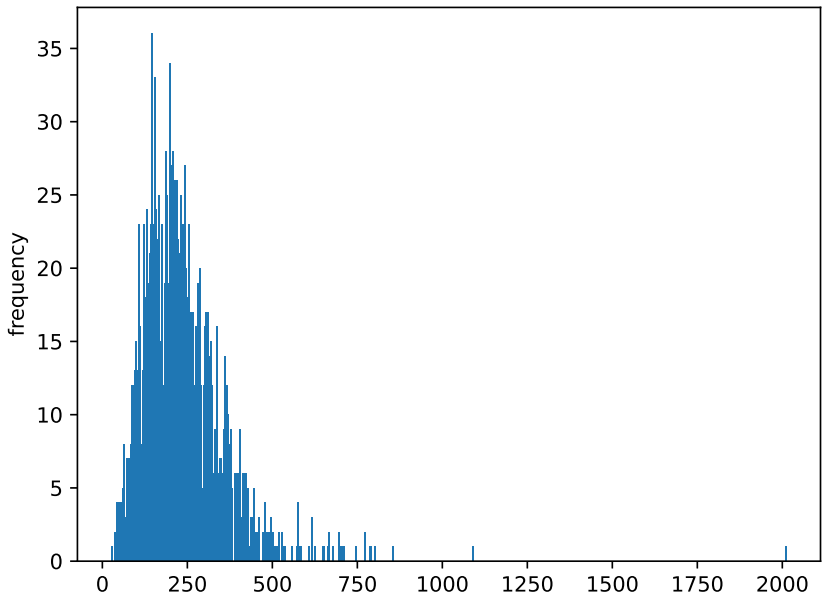

Figure 2. Histogram plot of the tokens count per abstract

between the authors. These cross-distances are the main contribution of our previous work [1]. We reintroduce them here to merge the results of the authors' social networks and the results of the distances between these authors.

A. General Approach of Processing

The goal of our implementation is to compare the results of the different BERT models and the different clustering techniques. In parallel, we extract the keywords for each text and use the generated labels (cluster labels) to map these keywords into their respective clusters. This attempts to assign a research field (a topic) for these clusters. We check the accuracy of such assignments by performing a coauthorship analysis afterwards. Figure 3 shows the implementation overview of the processing pipeline. The abstracts are fed to the BERT models as input to generate the high-dimensional encodings (or HD vectors), with each HD vector representing its respective abstract. We cluster the HD vectors using the different clustering techniques (centroid- and density-based) to obtain a set of 1,459 labels. Each label is a natural number from 0 to n (for n+1 clusters). We map the HD vectors onto the 2D plane to plot them with label-based coloring. We take the text of each abstract, extract its keywords using KeyBERT, and form clusters of keywords by assigning each set of extracted keywords the respective label of the abstract HD vector.

In terms of centroid-based clustering, we set the clustering process to perform 10 runs, each run with *maximum_iterations* set to 100. At the end of each run, we calculate the sum of the three chosen metrics: Silhouette, Calinski-Harabasz, and Davies-Bouldi. At the end of this iterative process, we take the labels that correspond to the highest sum. We record our results for future reference.

B. Distances between Authors

The database we use in our work contains a set of authors and their corresponding research papers.

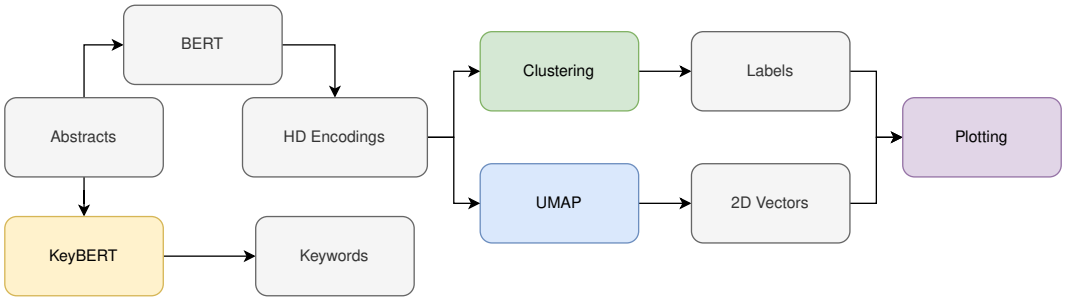

Figure 3. Implementation Overview

We have encoded each paper using BERT models and computed the average distance between the encodings of each pair of authors, which we refer to as the cross-distance. The cross-distance is an indicator of the similarity between two authors in terms of their research topics. Let P_1 be the set of papers by author 1 (A_1) and P_2 likewise be the set of papers by author 2 (A_2). Then the distance between authors 1 and 2 is defined as:

$$crossDistance(A_1, A_2) = \frac{\sum_{p_1 \in P_1} \sum_{p_2 \in P_2} \text{dist}(p_1, p_2)}{|P_1| \cdot |P_2|} \quad (1)$$

We have analyzed the self-distance of each author by computing the average distance between the encodings of their own papers. A lower self-distance value reflects the author's precise focus on a specific field. Our previous study [1] has revealed that if two authors have coauthored one or more papers, their cross-distance value is on average lower than the total average distance value, indicating a higher similarity in research topics. Furthermore, we have found that authors with lower self-distance values tend to have a more precise research focus. This demonstrates the effectiveness of the BERT model in encoding research papers to identify similarities between authors in terms of research topics.

We employ the concept of cross-distances to investigate the correlation between the authors' self-distances and their respective number of connections within their social networks.

6. Experiments

In this section, the experiments done throughout this work and both the rationale behind them and the results obtained from them are discussed.

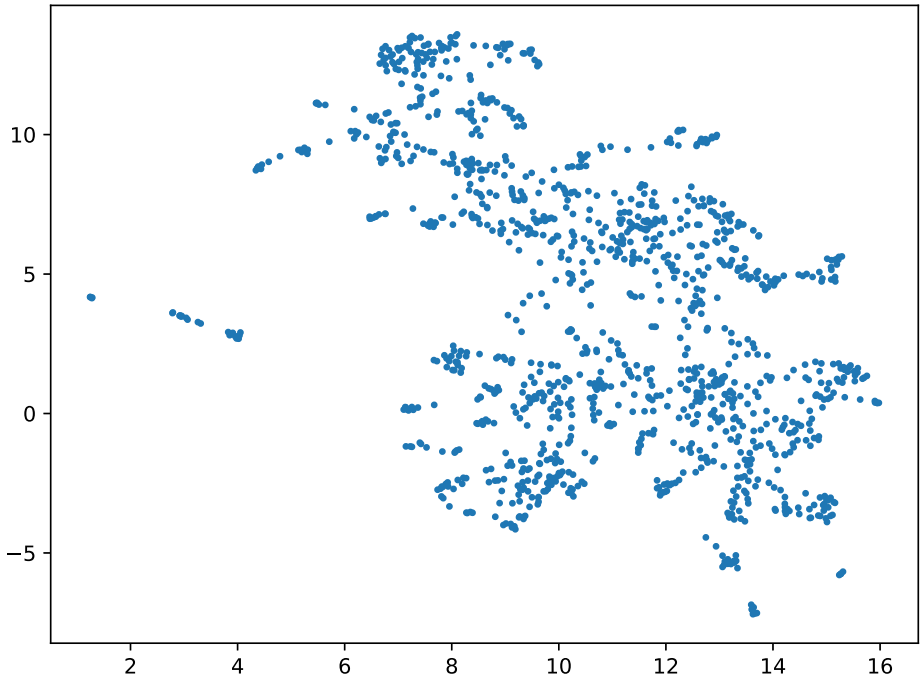

Figure 4. Scatter Plot of UMAP-Reduced SciBERT Encodings

In our previous work [1], the focus was on the Base-BERT model. However, this has two drawbacks: It is not specialized in scientific articles, and it does not cover multilingual input very well. Here, the focus is on investigating and comparing two other models: SciBERT, which is trained specifically on scientific articles, and mBERT, which is trained on multilingual data. A side comparison with BERT models trained on German data is also provided.

A. Scientific text-oriented Processing: SciBERT

SciBERT is a modified version of BERT that was trained on scientific text data. The training process for SciBERT was similar to that of BERT, but with some modifications to better handle scientific language. To train SciBERT, the researchers used a large corpus of scientific papers from a variety of fields, including computer science, biology, and physics. The corpus was preprocessed and tokenized in the same way as BERT, using the WordPiece algorithm. The architecture of SciBERT is the same as that of BERT, but the pre-training process was modified to better handle scientific language. The resulting model has been shown to outperform BERT on a range of scientific text-related tasks, including named entity recognition, relation extraction, and sentence classification. We select only the English papers in the database and encode them with SciBERT (our data includes both English and German papers). Figure 4 shows the UMAP-2D vectors of the SciBERT encodings.

We cluster the high-dimensional vectors that are generated by SciBERT using K-means to observe the initial distribution of the English papers. We cluster the high-dimensional vectors instead of the 2D-mapped vectors because the HD vectors contain more information, while the mapped ones are only their projections. The distance between a pair of HD vectors is not in correlation with the distance between the pair of their respective projections. This is also known as the binary stars situation. Figure 5 shows the K-means clusters of the SciBERT encodings (7 clusters). We have noted on the figure the titles of two papers from two clusters randomly selected. By reading these titles, we observe that there might be a similarity of topics in each cluster. For reference, Silhouette, Calinski-Harabasz, and Davies-Bouldin scores are 0.102, 112.266, and 3.067, respectively.

To investigate this, we extract the keywords of the papers in each of these clusters through our KeyBERT-based processing pipeline. Table II displays the major keywords of each cluster. From this table, we observe that despite the similarity between clusters 0 and 6 and the ambiguity of cluster 2, each of the other clusters has a distinct field. However, the data that was fed to SciBERT

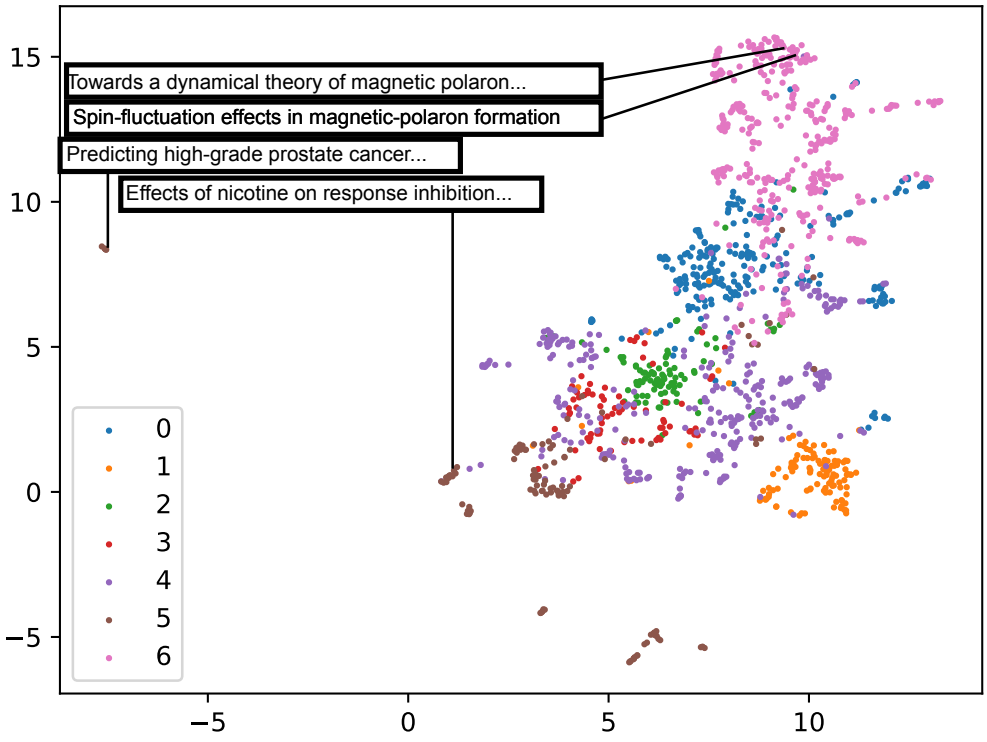

Figure 5. K-means Clusters of SciBERT Encodings (English only)

cluster	keywords
0	exciton, quantum, magnetic, electron, polaron
1	video, classification, recommender, data, 3d
2	computer tomography, systems, digitalisation, management
3	optical, polishing, surface laser, machining
4	melanoma, gene, macrophage, health, biomarker
5	renewable, solar, photovoltaic, sensor, microgrid
6	dielectric, plasma, microscopy, nanowire, oxide

Table 2: KeyBERT-generated Cluster keywords of SciBERT encodings

did not include the German papers. Therefore, we process these papers using German-trained BERT models, as they have been cast out of the processing pipeline so far.

B. Non-English Data: Processing German Papers

As previously mentioned, the vectors representing the papers written in German were put into one cluster, as SciBERT has embedded the German texts very similarly to each other, and distinctively from the English texts. The obtained similarity, however, only represents linguistic differences and is not topic-based.

We chose the transfomer models that were trained specifically on German data: German Base-BERT Cased, and German Base-BERT Uncased (DBMDZ).

- *Cased German Base-BERT:* The authors trained on a single cloud TPU v2 with the default settings using Google's Tensorflow code. They trained 30k steps with a sequence length of 512 and

810k steps with a batch size of 1,024 for sequence lengths of 128. While it takes roughly nine days to train, they used news articles, the most recent German Wikipedia dump (6GB of raw txt files), and the OpenLegalData dump (2.4 GB) as training data (3.6 GB). With the help of customized scripts and spacy v2.1, they cleaned the data dumps and utilized the suggested sentencepiece library to build the word piece vocabulary and tensorflow scripts to turn the text into data that could be accessed by BERT in order to construct tensorflow records.

- *Uncased German Base-BERT (DBMDZ):* The work offers another German-language model in addition to the released German BERT model from deepset. A recent Wikipedia dump, the EU Bookshop corpus, Open Subtitles, CommonCrawl, ParaCrawl, and News Crawl make up the model's underlying data. As a result, a datase with 2,350,234,427 tokens and a 16 GB size is produced. The authors employed spacy to separate sentences, and the same preprocessing techniques as those used to train SciBERT (sentence fragment model for vocabulary creation). The model underwent 1.5 M steps of training with a starting sequence length of 512 subwords.

We chose to use both cased and uncased models for the German language because while uppercase nouns may suggest that case is more significant in German than in English, it does not necessarily mean that a cased model will perform better on all tasks. In cases like part-of-speech detection, it is unclear whether the benefits of having a much larger vocabulary from using a cased model outweigh the added complexity. Cased models have separate vocabulary entries for differently-cased words. To observe the potential variations that could occur with different casings, we applied each model to the data and clustered the resulting vectors. Figures 6 and 7 display the outcomes of the cased and uncased models, respectively.

The uncased model in Figure 7 has produced vectors that are closer to each other (in terms of their 2D projection) than the cased model in Figure 6. The latter model apparently makes a sharp distinction between one of the clusters (top left) and the rest. However, the clusters in each graph could not be distinguished to the point of falling into a certain field or topic. As for clustering metrics, the scores of Silhouette, Calinski-Harabasz, and Davies-Bouldin for the cased German BERT are 0.100, 19.480, and 2.815, respectively. Whereas for the uncased German BERT, these respective scores are 0.047, 8.879, and 3.326. Table III shows the keywords of these clusters. From Table III,

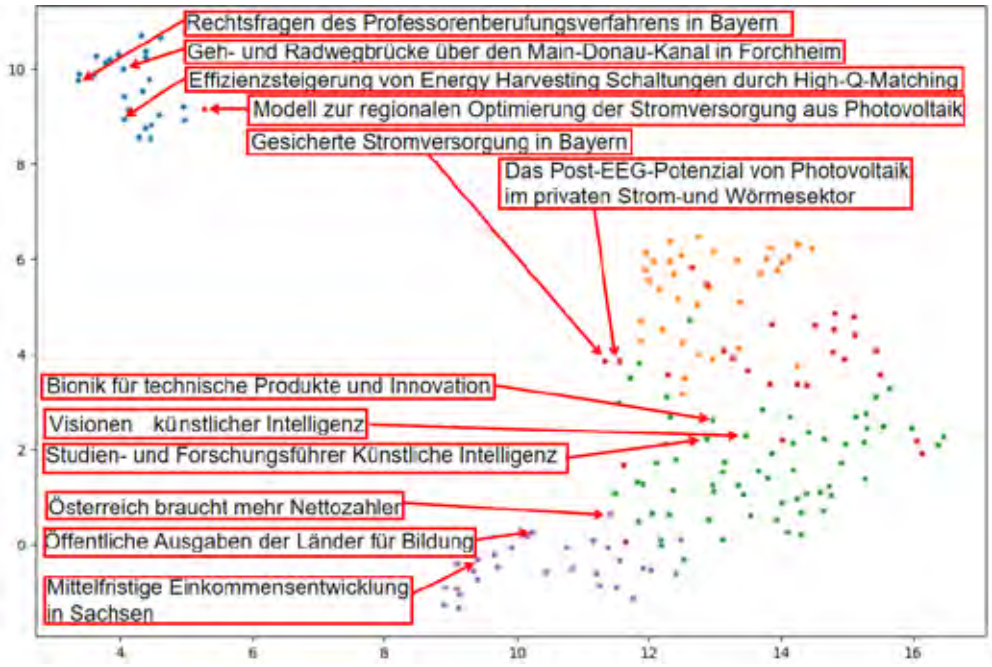

Figure 6. Scatter Plot (Clusters) of UMAP-Reduced Encodings of German Base-BERT Cased

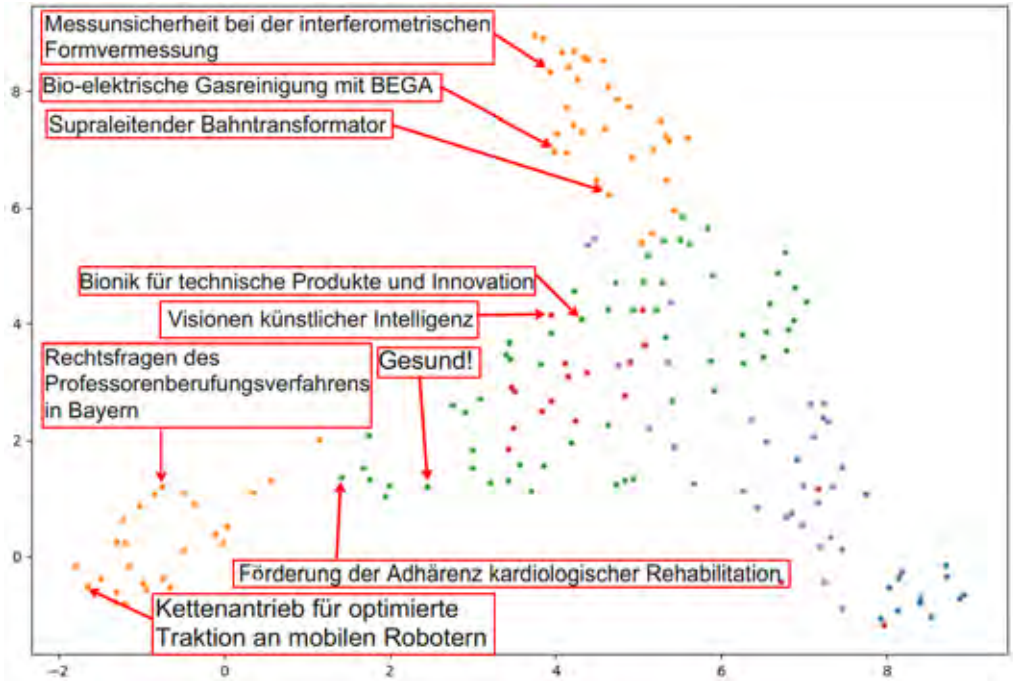

Figure 7. Scatter Plot (Clusters) of UMAP-Reduced Encodings of German Base-BERT Uncased (DBMDZ)

Cased German BERT	
cluster	**keywords**
0	metallkörper, datenanalyse
1	computertomographie, visualisierung
2	digitalisierung, innovationsnetzwerke
3	innovationsmanagement, digitalisierung
4	beschäftigung, bevölkerung
Uncased German BERT (BDMDZ-BERT)	
cluster	**keywords**
0	beschäftigung, bevölkerung
1	faserverbundkunststoffe, ethernet
2	digitalisierung, innovationsmanagement
3	lernortkooperation, destinationsmanagement
4	diskriminierung, arbeitseinstellung

Table 3: Cluster-Keywords Table for German Papers

the exclusive processing of German papers was not exact enough to the point of drawing clear topics, which in turn could represent the landscape of research published in German by the institute.

The uncased model presented in Figure 7 yielded vectors that were more closely situated (based on their 2D projection) than the cased model depicted in Figure 6. The latter model sharply separated one of the clusters (top left) from the others. However, neither of the models allowed for clear differentiation among the clusters with respect to particular fields or topics. In terms of clustering metrics, the Silhouette, Calinski-Harabasz, and Davies-Bouldin scores for the

cased German BERT are 0.100, 19.480, and 2.815, respectively. By contrast, the respective scores for the uncased German BERT are 0.047, 8.879, and 3.326. Table III presents the cluster keywords of these clusters. Overall, our exclusive processing of German papers did not achieve sufficient granularity to reveal distinct research topics that might represent the landscape of German research published by our institute. Therefore, we intend to utilize a multilingual BERT model that can process all of the papers at once to construct the clusters in an appropriate way that spans the whole set of abstracts.

C. Processing Multilingual Data: mBERT

Multilingual BERT (mBERT) is a language model developed by Google that can understand and generate text in multiple languages. It is trained on a large corpus of text from 102 different languages, allowing it to effectively model and generate text in diverse linguistic contexts. mBERT uses a transformer-based architecture that employs bidirectional encoding to capture contextual relationships between words in a sentence. This architecture enables it to perform a range of natural language processing (NLP) tasks such as named entity recognition, sentiment analysis, and machine translation. Additionally, mBERT is capable of performing cross-lingual transfer learning, which means that it can transfer knowledge from one language to another and use this to improve the accuracy of its predictions. These features make mBERT a powerful tool for multilingual NLP tasks and have led to its widespread use in academia and industry.

We use mBERT to encode all of the papers in our database. This permits a complete representation of the research landscape in the institute, based on which we generate more fitting clusters. We can then investigate the appropriateness of the formed clusters (in terms of topic) by observing the extracted keywords from each cluster and performing a coauthorship analysis. The mBERT encodings of our data are mapped onto a 2D plane and plotted in Figure 8. The vectors produced by mBERT can be seen to be held on one continent, which initially indicates an appropriate handling of papers regardless of the human language used (as each of our papers is written in either English or German).

We now perform the clustering process on the generated mBERT encodings. The obtained clusters are shown in Figure 9. We have noted on the graph a few random points from each cluster. The initial observation is that the points in each of the groups 1, 2, and 4 fall in one field: computer tomography in group 1 (computer science department), Chinese-German medicine in group 2 (health department), and energy in group 4 (power department). Group 3 is an example of points that appear far on the graph but still fall under one topic (health).

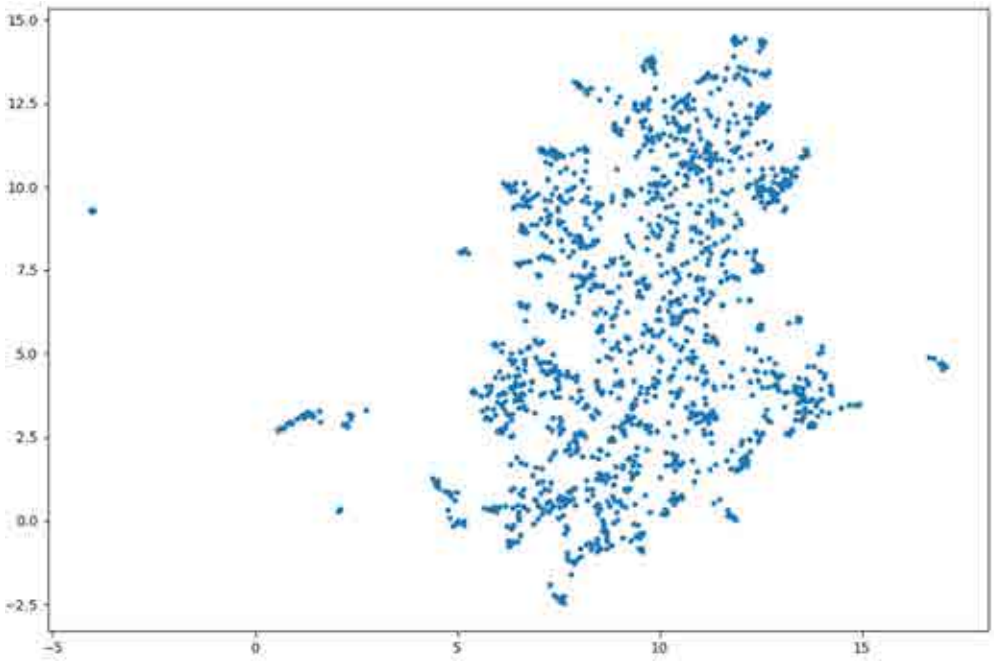

Figure 8. Scatter Plot of UMAP-Reduced mBERT Encodings

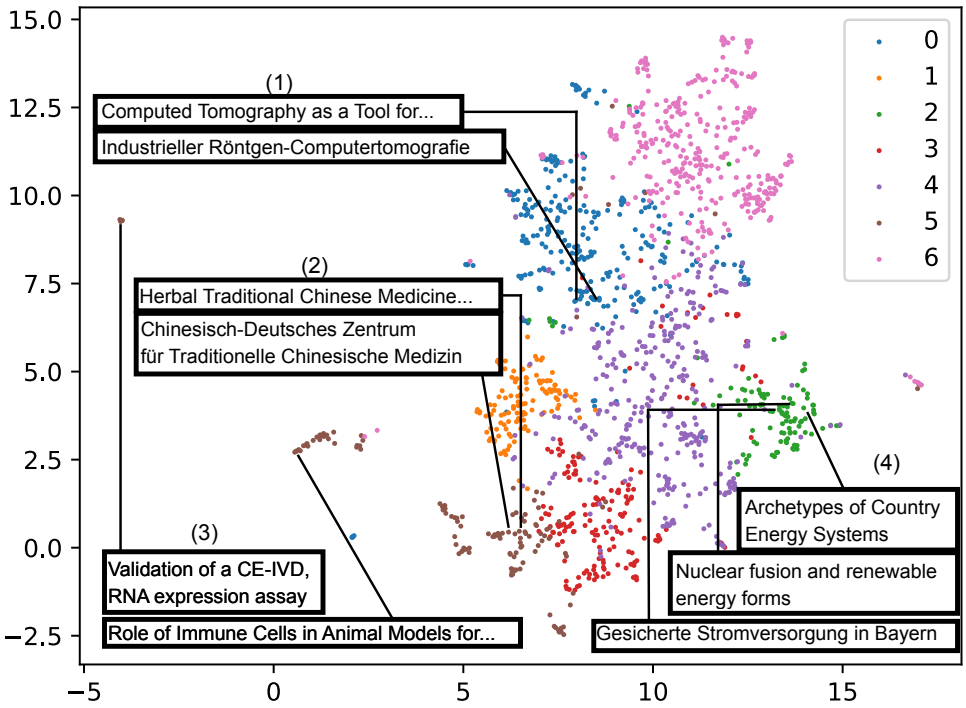

Figure 9. Clusters of mBERT Encodings (multilingual set of papers)

Multilingual Data		
cluster	**keywords**	**topic (manual)**
0	polishing, grinding, welding	Manufacturing
1	3dtv, stereoscopic, resolution	Media
2	renewable, emissions, photovoltaic	Power
3	tourism, resorts, pension	Economics/Management
4	classifier, recommender. virtualization	Computer Science
5	prostate, aerobic, schizophrenia	Health
6	nanowire, dielectric, semiconductor	Material

Table 4: Cluster-Keywords Table of Multilingual BERT

The mBERT model has encoded similar papers close to each other regardless of their language (represented by groups 1, 2, and 4 on the graph). The HD-vector clustering appears to be accurate, as each group of papers is held in their own shared cluster, although UMAP has mapped them far from each other at times in 2D (group 3). For reference, the Silhouette, Calinski-Harabasz, and Davies-Bouldin scores are 0.035, 30.369, and 4.468, respectively.

We extract the keywords for each of the formed clusters using KeyBERT to obtain the general topic of each of them. Table IV shows the result of the keyword extraction process. The topics formed from the keyword extraction are the most precise so far (even distinguishing between Media Engineering and Computer Science papers). Having a consistency of keywords across each cluster while spanning all data regardless of human language makes the generated clusters a good reflection of the topics in our database. The observed topics match the departments that are active in research at the DIT. The topics of health, economics, and computer science match their respective departments. The materials topic is in the natural sciences department. Manufacturing is divided

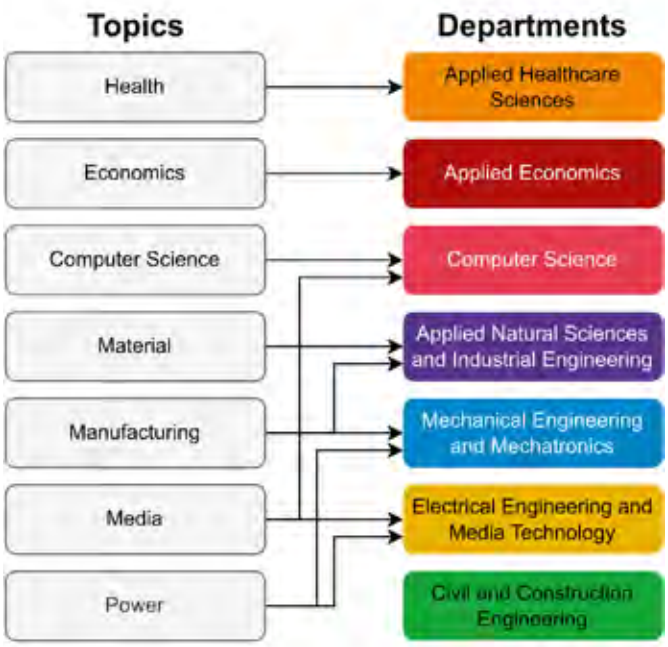

Figure 10. The Observed Cluster Topics in relation to the Departments at the DIT

between the departments of natural sciences and mechanics. Media is also divided between media and computer science departments, and power is divided between electrical engineering and mechanics departments. The department of civil engineering lacks the respective cluster, which is the product of having a smaller set of research papers in comparison to the other departments. This is shown in Figure 10. There exists an 8th department at the DIT, which is the European Campus Rottal-Inn. This department offers a set of different programs, such as industrial engineering and digital health. The papers from this department do not have a common topic but fall into different ones. Therefore, it was topically indistinguishable in the formed clusters.

However, as our dataset is unlabeled, it remains difficult to determine the reliability of the constructed clusters. Therefore, we go beyond the systematic use of cluster metrics by employing the coauthorship aspect of our data to determine the accuracy of this topical clustering.

D. Authors and Clusters: A Relationship to Investigate

In Subsection V-B, we have stated the term *self-distance*. This self-distance represents the breadth of research topic for each author (introduced in our previous work [1]). We have observed that even the author with the highest self-distance publishes in one cluster. If authors generally publish their papers in one cluster (one topic), the exclusiveness of authors within a cluster is an indication of its construction accuracy.

Let L_n be the list of clusters $(C_0, C_1, ..., C_k)$ that author A_n is involved in, and $IP(A_n,C_m)$ the Involvement Percentage of author A_n in cluster C_m. $IP(A_n,C_m)$ is then defined as:

$$IP(A_n, C_m) = \frac{count(C_m \in L_n)}{|L_n|}$$

The Uniqueness Percentage $UP(C_m)$ of a cluster C_m, in terms of how exclusive the authors in the list of its authors U_m, is defined as:

$$UP(C_m) = \frac{\sum_{A_n \in U_m} IP(A_n, C_m)}{|U_m|}$$

Figure 11 shows the results of our UP calculations. The lowest average percentage of *uni-clusteric* authors is 80.85% (cluster 3), meaning that most clusters have over 80.85% of unique authors. Although the papers of an author are generally of one cluster, the authors can branch out and collaborate with other researchers in different fields. For example, if *author* A publishes mainly on computer science

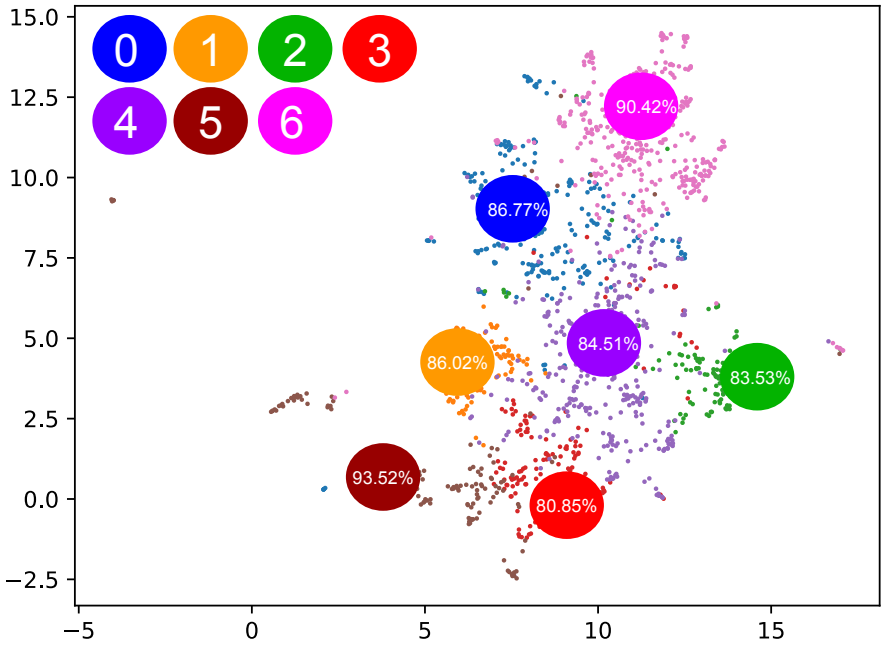

Figure 11. The Uniqueness Percentage of Each of The 7 Clusters in mBERT Encodings

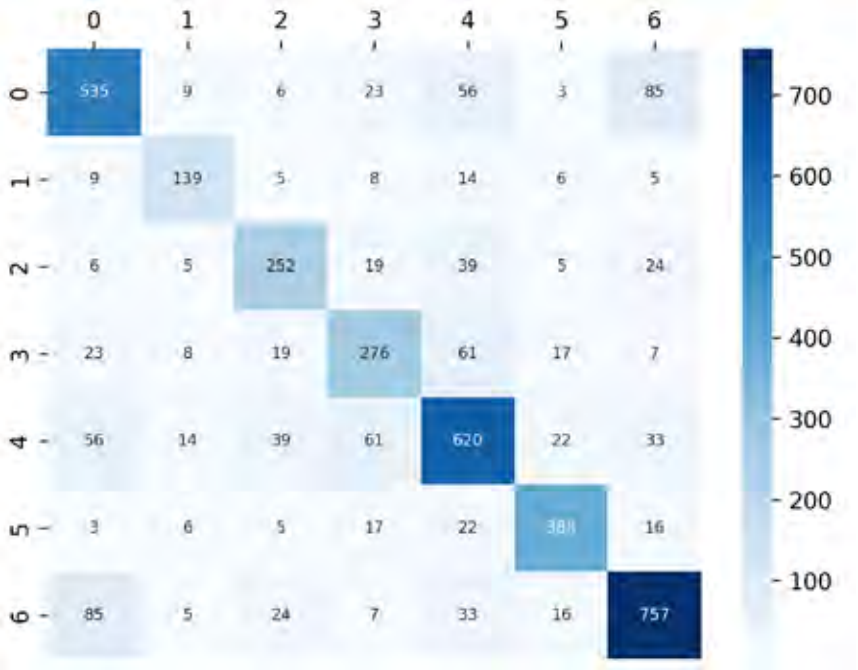

Figure 12. Total Count of Authors in Each Cluster, Along with Count of Shared Authors

topics (cluster 4), but occasionally collaborates with colleagues in the medical sciences field (cluster 5), *author* A is said to be a shared author between clusters 4 and 5. The example of an author being mainly in one cluster and branching out on a few occasions is practical. To visualize the authors shared between cluster pairs, we plot the number of authors inside each cluster and the number of shared authors between them, as shown in Figure 12. We observe a few pairs of clusters that share high numbers of authors, such as clusters 0 and 6 (85 shared authors), clusters 0 and 4 (56 shared authors), and clusters 3 and 4 (61 shared authors). The topics of two clusters can be close enough to overlap, implying authors with papers in both topics, such as clusters 0 and 6 with Industry and Material Engineering or clusters 3 and 4 with Computer Science and Economics (Econ-Informatics being a major sub-department of

Economics). We have observed that our papers contain the general case of authors publishing in one cluster but still coauthoring research with different-field authors on shared topics (or topics that make use of two different fields, such as image processing in medical engineering). The percentage of unique authors (over 80.85%) in each cluster implies an initial indication of an accurate topical clustering of papers. However, to affirm such an indication, we use our data to construct social networks based on coauthorships between researchers. The construction of connected components (research groups) with topical homogeneity would affirm the accuracy of the topical clustering.

E. Constructing Social Networks of Research Groups

We construct the social networks that reflect the relationships between the authors. The constructed connected components are expected to represent the research groups, in which the authors take part. The authors are grouped by *coauthorship*, with coauthors as edges to the components. Using the *networkX* library, the connected components of authors are formed. Figures 13 and 14 show the correlation between the edge count and the self-distance of each author and the bar plot of that distribution per author.

Figure 13 indicates that edge counts are exponentially proportional to the self-distances (representing the topic breadth of an author). Therefore, the more topics an author has, the more likely it is that connections will be made. The number of connections in this case is represented by the edge count. In Figure 15 we plotted the edge count in relation to cluster count. It shows that the higher the number of authors in a component, the higher the number of clusters included.

Concerning the node colors in the following graphs, an author with papers strictly falling into one cluster is assigned the color of this cluster. The color gray is assigned to authors having papers in different clusters. We observe the obtained cases in the formed networks:

1) Single paper with multiple authors: Figure 16 shows an example for a single paper written by 7 authors.

2) Close cooperation between authors: Some groups of authors cooperate very closely. In such a case, we expect a small, fully connected graph where every person cooperates with every other person. Such a case is presented in Figure 17. Three authors work in the same field, publishing three different papers with each other. The group is isolated from other researchers but closely knit within itself.

3) Close research network: When different research groups work in the same field, cooperation between them is relatively easier. Figure 18 shows a case of different research leaders (marked with blue) collaborating with each other. When these researchers collaborate, they do not always bring their groups with them. Groups 1, 2, 3, and 4 are not connected. However, groups 4 and 5 are partially connected. The lead researchers of groups 1, 2, and 3 are fully connected to these groups, despite their blindness to each other. The research leaders are all connected to each other, except for the one marked in red. The multiple works (13 papers) of this close research network are all assigned to the same cluster 6 (field of Materials). This indicates accurate topical clustering.

4) Leader of research group: A senior researcher can be the leader of multiple research groups. Figure 19 shows an example of one internal research leader (gray node) and the multi-topical research associates. The gray node is connected to every other node in this component, indicating that the leader has worked with every other apparent associate in the graph. At least 7 distinct research groups can be identified. The distinction between two groups is drawn from the nodes of each group connecting only within. The node with the blue mark signifies a vice-leader between groups 1 and 2. A research leader with distinct yet same-field groups indicates that different yet close topics are addressed. For example, if a research leader publishes in both computer vision and natural language processing, the papers produced are going to fall into the computer science field. However, this leader can work with two distinct groups, each focusing on one topic in the field. The research leader in the graph has branched out in two papers (one in computer science and the other in power engineering). All of the other papers are by teams focusing on materials engineering. The occasional interconnections between the same-field groups, along with the absence of connections between the different-field groups, affirm the topic-clustering accuracy.

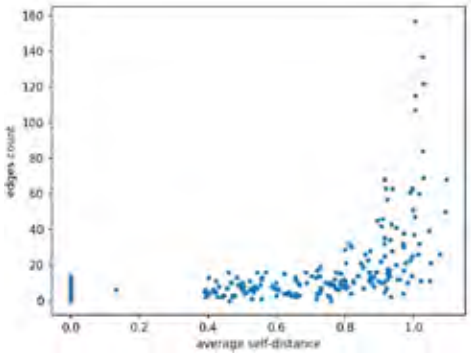

Figure 13. Scatter Plot of Edges Count of Authors in Relation to their Respective Average Self-distance

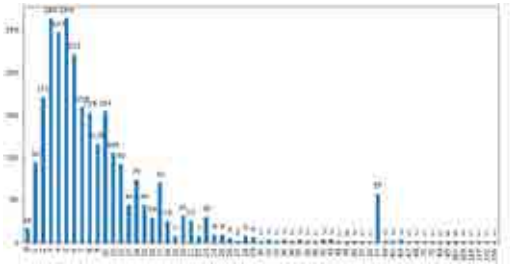

Figure 14. Bar Plot of Edges Count Per Authors (x-axis: number of edges for an author, y-axis: number of authors having n-edges)

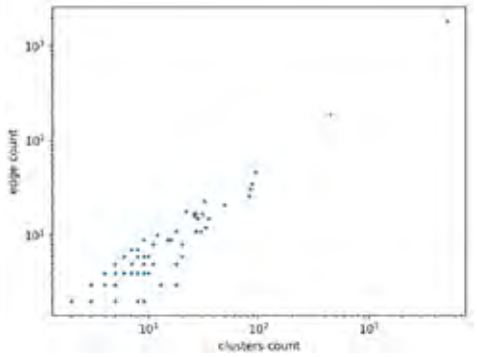

Figure 15. Scatter Plot of Edges Count in Relation to Cluster Count in the formed Social Networks

Figure 16. Connected Component For Single Multi-author Paper

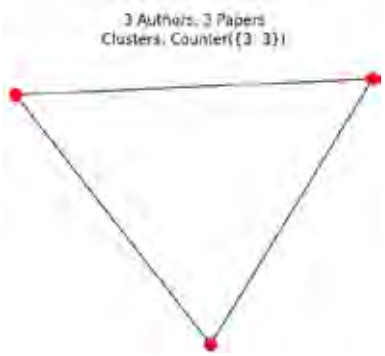

Figure 17. Connected Component For Same Authors Repeatedly

Figure 18. Connected Component For Close Research Network

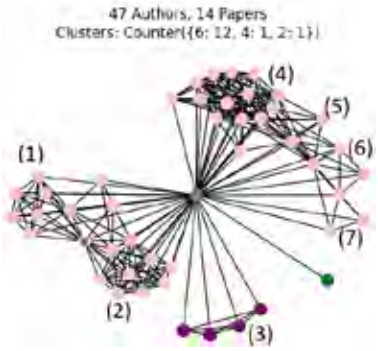

Figure 19. Connected Component For Internal Research Leader

Figure 20. Connected Component For A More Complex Research Network

clusters	0	1	2	3	4	5	6
paper count	240	115	87	62	252	115	232

Table 5: Cluster-Counter Table of the largest component

5) Complex research group: Research groups can take a complex form that is difficult to comprehend. Figure 20 shows an example of such a complex research network. There are 9 authors that have published in different fields (gray nodes). At least 1 out of these gray authors has published in 3 fields: materials, power, and economics. The gray nodes take a central position in the graph, whereas the others are drawn peripherally. These centralized authors are considered to bring research together in a relatively small format on different topics.

6) The largest component: Research groups are assumed to be topically isolated within the DIT. However, other than the minority of the isolated networks (such as the ones presented previously), the majority of authors are contained in a large connected component, displayed in Figure 21 (bigger nodes represent the internal authors). This large component is composed of 1,832 authors having 1,103 papers. The cluster counter is recorded in Table V.

In the network, the internal authors are connected closely to their research groups (on both ends). However, they always make a connection with other authors (often internally). This action snowballed to the point of creating such a massive network. The internal authors, having a few topics, collaborate occasionally with each other to form a circle that keeps the research connected within the institute. The collaborations always include at least one multi-clustral author, whose associates are joint-in. These gray authors are the reason for such formation. We deduce the following points from this large structure:

- Research covering different fields can be attractive. Especially with the availability of different yet close fields in the institute of applied sciences. A topic in power engineering can have an industry or material aspect to it. The same applies for other topics in computer science and media engineering. Also, many topics in the health department use technologies developed through research in computer science.
- Other than this, the employment of a generated result in a different topic than its generation-related topic is a valid attempt to extrapolate these results.

Contrary to our expectations regarding the structures of social networks, there exists a set of internal authors whose collaborations with each other form this large network. The ends of this major component represent the research groups of these internal authors. In each of these ends, there exists topic homogeneity. This indicates that the research groups of these internal authors also follow the same topical pattern as the isolated groups. If the collaborations between these internal authors are removed, the large network breaks down into smaller components that follow similar patterns as presented previously, implying an accurate topical clustering of the BERT encodings.

7. Conclusion

This article deals with the topical clustering of the scientific papers in the internal publications database of the DIT. The transformer-generated encodings of these papers reflect their corresponding topics. We investigated the topical clustering of such unlabeled data. In our previous work [1], we established a methodology for calculating the cross-distance between a pair of authors based on the respective encodings of their papers. We utilize such a methodology to investigate the topics in the clusters. This previous work focused on the use of Base-BERT and SciBERT and ignored the non-English papers. We reintroduced SciBERT and the centroid-based clustering technique (K-means). We extracted the keywords for each cluster and observed an ambiguity in the keywords of the generated clusters. In parallel, we investigated the non-English papers in our data (German papers) by using both cased and uncased models. We analyzed the minor differences between the two models and extracted their cluster keywords. However, to generate a single landscape for all papers, we employed a multilingual BERT model (mBERT). mBERT was efficient in generating a research landscape that included all papers. Although the texts are

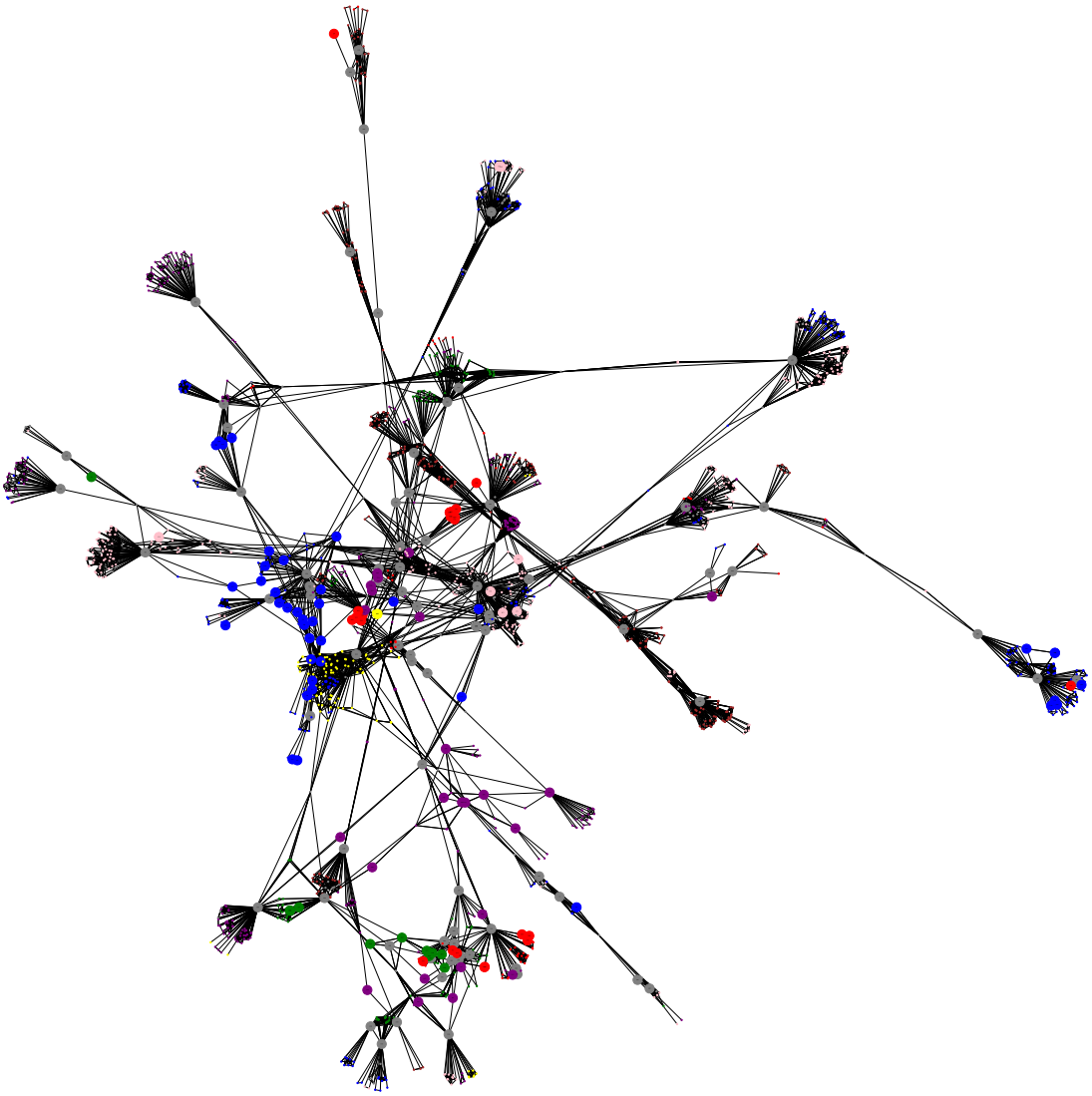

Figure 21. The Largest Connected Component

written in scientific language, mBERT showed acceptable results, as its clusters (and their keywords) matched the research departments of the DIT, despite the fact that mBERT is not trained specifically on scientific data (compared to SciBERT). The keyword-based approach of relating the researchers (the previous approach of relating authors [22]) is more language-dependent than our new transformer-based approach. The model mBERT makes it possible to transcend language barriers. Two papers written in different languages but focusing on similar topics, are encoded into relatively close vectors by mBERT. This ability provides accuracy in the topical clustering of different papers, contextually and regardless of their languages. Our work with mBERT finalizes a major point in the future work section of our previous paper [1]. Due to the absence of labels, the clustering metrics cannot fully affirm the accuracy of the topical clustering. We resorted to keyword extraction and coauthorship analysis, making use of the coauthorship aspect of our textual data. The first part of the analysis involves investigating the uniqueness of the authors in each cluster. Our calculations indicated a high uniqueness percentage of authors in each cluster (over 80%). The second part of the coauthorship analysis is the construction of coauthorship-based social networks. The constructed components contain a large network. This large network holds 74% of internal authors, whose collaborations with each other are key to this large formation. Without these collaborations, the large network decomposes into a set of small components that have a similar structure to the other networks. The construction of coauthorship-based social networks showed

topic homogeneity in the formed components, which represent the research groups at the DIT. Taking all this into account, we conclude that the generated clusters are semantically meaningful.

In our research, we employ pre-trained models without undergoing any fine-tuning. Consequently, the methodology and approach presented here can be applied to analogous publications databases. While the comprehensiveness of the respective outcomes cannot be guaranteed until they are investigated, similar results are to be expected. Still, a limitation of our work is the absence of text for other publications, such as presentations, interviews, or similar. The data used here is limited to research papers only. Although we do not use other types of publication, we fully acknowledge the importance of such contributions. Our decision to focus on only research papers with abstracts stems from the need for the availability of an expressive text for each item, permitting the transformer models to encode it in a comprehensive way.

In future work, we will consider how to incorporate other types of publication into our approach. Moreover, graph neural networks can be employed to predict the missing connections in the co-publication graphs. Enhancing the keyword extraction process leads to an accurate semantic meaning for the clusters formed by K-means in the latent space of publication vectors. The large social network can be used to identify the connecting researchers. We have also performed preliminary experiments with DBSCAN on the HD-vectors that need to be focused in the future.

Acknowledgement

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Resonant Low-Frequency Electromagnetic Biostimulation of *Lepidium sativum* Short: ELF-EMF Beats

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ABSTRACT

Low-frequency electromagnetic waves were applied to *Lepidium sativum* (garden cress) in order to alter their germination and seedling properties. Two different methods were used to generate the electromagnetic signals. Either a 1.8 GHz carrier signal was multiplied with an extremely low frequency signal (between 1 Hz and 200 Hz) – also called amplitude modulation – or, as the second method, a beat signal of two high-frequency electromagnetic waves with very similar frequencies was created. The generated amplitude modulated signals were sent to an antenna for emission of the waves to free space. In close vicinity to the antenna, seeds of garden cress were placed in a moist environment. The seeds were exposed to the electromagnetic waves initially for 20 minutes and subsequently every 24 hours for 20 minutes. After 100 hours, the length of the cress plants was measured. Within the measurement accuracy, a retarded growth was detected at extremely low frequencies of 50Hz. The growth inhibition was more pronounced with the beat signal than with the amplitude modulation. This method of beat signals opens up new possibilities to alter biological systems and more advanced topics than the germination and seedling of garden cress will be explored in future work.

Lepidium sativum *(Gartenkresse) wurde mit niederfrequenten elektromagnetischen Wellen bestrahlt, um ihre Keimung und ihr initiales Wachstum zu beeinflussen. Zwei verschiedene Methoden zur Generierung der niederfrequenten elektromagnetischen Signale wurde verwendet. Zum einen wurde ein 1,8 GHz Trägersignal generiert, welches mit einem extrem niederfrequenten Signal (zwischen 1 Hz und 200 Hz) multipliziert wurde – zumeist als Amplitudenmodulation bezeichnet. Zum anderen wurde eine Schwebung erzeugt durch die Überlagerung zweier hochfrequenter Wellen mit sehr ähnlichen Frequenzen. Diese Signale wurden mittels einer Antenne in eine abgestrahlte elektromagnetische Welle umgewandelt. In der Nähe der Antenne wurden Samen der Gartenkresse in einer feuchten Umgebung platziert. Die Samen wurden initial 20 Minuten bestrahlt und anschließend alle 24 Stunden für 20 Minuten. Nach 100 Stunden Keimung und Wachstum wurde die Länge der Kresse bestimmt. Im Rahmen der Versuchsgenauigkeit wurde ein verringertes Wachstum für eine Frequenz von 50 Hz ermittelt. Hierbei war die Wachstumsverringerung bei Verwendung der Schwebung größer als bei Verwendung der Amplitudenmodulation. Somit eröffnet die Methode der elektromagnetischen Schwebung neue Möglichkeiten, biologische Systeme zu beeinflussen und bedeutsamere Themen als die Keimung und das Wachstum von Gartenkresse werden in zukünftigen Arbeiten untersucht.*

KEYWORDS

Biostimulation, garden cress, ELF-EMF, beat, amplitude modulation

Biostimulation, Gartenkresse, ELF-EMF, Schwebung, Amplitudenmodulation

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1. Introduction

Biostimulation with extremely low-frequency electromagnetic fields (ELF-EMF) is an emerging area for alternative medical treatment [1–3] and for biotechnological applications [4–5]. One way of explaining the effect of the ELF-EMF on living organisms is the concept of forced oscillation. Many processes in biological materials are based on electrical signals of ion transport or are mediated by electric fields within an organism with function-dependent frequency. If an external electromagnetic stimulus is applied with a frequency similar to the eigenfrequency of the process, a resonantly forced biostimulation occurs. Dependent on the process which is affected, this electromagnetic biostimulation can have positive or negative effects on the organism.

Different concepts for electromagnetic biostimulation exist in literature. The most common method is the generation of ELF-EMF by magnetic coils. The research field can be divided into three groups: human brain stimulation (mostly named "transcranial magnetic stimulation" [6]) and human body treatment in general, second the alteration of the growth of bacteria [7,8] and third, changing the germination and seedling of plants [4,9–11]. For the research related to effects on plants, the initial stage of germination and seedling of the plants have been focused on and both, the increased and decreased growth of plants under ELF-EMF radiation generated by magnetic coils have been reported [9]. Mechanisms behind these effects are not fully understood to date but one hypothesis is that the activation of ions and the polarization of dipoles in living cells might be influenced [9].

Another method for the creation of ELF-EMF is the generation of an amplitude modulated electromagnetic wave. One functionality of modern high-frequency signal generators is to create an extremely low-frequency signal envelope of a high-frequency carrier signal named amplitude modulation. These amplitude modulated RF signals were used to increase the calcium-ion efflux from brain tissue [11], to change the ornithine decarboxylase activity [12] and for the growth inhibition of bacteria [13–14] by inducing morphological changes in the bacteria.

In addition to the amplitude modulated electromagnetic wave method we also used an electromagnetic beat signal for the generation of ELF-EMF. A similar extremely low-frequency envelope of a high-frequency electromagnetic wave can be created by superimposing two high-frequency signals with almost the same frequency. The resulting beat signal has nearly the same ELF-EMF envelope as for the amplitude modulated one. To our knowledge, no experimental investigations of the effect of electromagnetic beat waves on living organisms has been published so far.

Here, we present an experimental work of electromagnetic biostimulation using a newly developed technique of electromagnetic beats in order to alter the germination and seedling of plants. Garden cress seeds (*Lepidium sativum*) are popular crop species and are commercially cultivated across the world. Garden cress has been chosen due to their fast germination and short seedling time.

2. Theory of amplitude modulation and beat generation

Amplitude modulation is a well-known technique in radio and information technology. A high-frequency electromagnetic signal (carrier signal) is multiplied with a low frequency signal where usually the information is transmitted by. This can be mathematically described as:

equation of electric field (as scalar) of carrier signal:

$$E_C(t) = A_C \cdot \cos(\omega_c t) \qquad (1)$$

with A_C the amplitude of the electric field and ω_C the frequency of the carrier signal; and
equation of electric field (as scalar) of modulation signal:

$$E_M(t) = A_M \cdot \cos(\omega_M t) \qquad (2)$$

with A_M the amplitude of the electric field and ω_M the frequency of the carrier signal.
For amplitude modulation the modulation signal is added with a DC component (which is set here to 1) and both are multiplied with the carrier signal:

$$E_{AM}(t) = [E_M(t) + 1] \cdot E_C(t) = A_M \cdot \cos(\omega_M t) \cdot A_C \cdot \cos(\omega_c t) + A_C \cdot \cos(\omega_c t) \quad (3)$$

rearranged: $\frac{E_{AM}(t) - A_C \cdot \cos(\omega_c t)}{A_M \cdot A_C} = \cos(\omega_C t) \cdot \cos(\omega_M t)$ (4)

now using the trigonometric identity (i): $\cos(\alpha) \cdot \cos(\beta) = \frac{1}{2}\cos(\alpha + \beta) + \frac{1}{2}\cos(\alpha - \beta)$

gives:

$$\frac{E_{AM}(t) - A_C \cdot \cos(\omega_c t)}{A_M \cdot A_C} = \frac{1}{2}\cos(\omega_C t + \omega_M t) + \frac{1}{2}\cos(\omega_C t - \omega_M t) \quad (5)$$

rear.: $E_{AM}(t) = A_M \cdot A_C \cdot \left[\frac{1}{2}\cos(\omega_C t + \omega_M t) + \frac{1}{2}\cos(\omega_C t - \omega_M t)\right] + A_C \cdot \cos(\omega_c t)$ (6)

rearranged: $E_{AM}(t) = A_C \cdot \left[\frac{A_M}{2}\cos(\omega_C t + \omega_M t) + \frac{A_M}{2}\cos(\omega_C t - \omega_M t) + \cos(\omega_c t)\right]$ (7)

rearranged: $E_{AM}(t) = A_C \cdot \left[\frac{A_M}{2}\cos([\omega_C - \omega_M]t) + \cos(\omega_c t) + \frac{A_M}{2}\cos([\omega_C + \omega_M]t)\right]$ (8)

equation (8) shows that the resulted amplitude modulation consists of the lower sideband $\frac{A_M}{2}\cos([\omega_C - \omega_M]t)$, the carrier signal $\cos(\omega_c t)$ and upper sideband $\frac{A_M}{2}\cos([\omega_C + \omega_M]t)$.

A similar modulation of the amplitude can be achieved by superimposing two closely spaced electromagnetic waves of same amplitude often referred to as a beat signal. Mathematically, a beat signal can be described by:

equation of electric field (as scalar) of the first signal: $E_1(t) = A \cdot \cos(\omega_1 t)$ (9)

and equation of electric field (as scalar) of the second signal: $E_2(t) = A \cdot \cos(\omega_2 t)$ (10)

if both signals are superimposed we get: $E_1(t) + E_2(t) = A \cdot [\cos(\omega_1 t) + \cos(\omega_2 t)]$ (11)

rearranged: $\frac{E_1(t) + E_2(t)}{A} = \frac{E_{beat}(t)}{A} = \cos(\omega_1 t) + \cos(\omega_2 t)$ (12)

We here use the trigonometric identity (ii): $\cos(\alpha) + \cos(\beta) = 2\cos\left(\frac{\alpha+\beta}{2}\right) \cdot \cos\left(\frac{\alpha-\beta}{2}\right)$:

$$E_{beat}(t) = 2 \cdot A \cdot \cos\left(\left\{\frac{\omega_1 + \omega_2}{2}\right\} \cdot t\right) \cdot \cos\left(\left\{\frac{\omega_1 - \omega_2}{2}\right\} \cdot t\right) \quad (13).$$

If $E_1(t)$ and $E_2(t)$ are very similar frequencies then this beating signal consist of a high-frequency part (like the carrier signal) multiplied with a low-frequency part – the envelope. The difference of the amplitude modulated signal is that a constant part (here „1“) is added to the low-frequency signal – see equation (3) – which results in three frequency contributions: the carrier frequency and two sidelobes. Without this constant part the amplitude modulated signal would be identical with the beat signal.

3. Experimental setup

For generation of the amplitude modulated signal, a signal generator Siglent SSG3000X and a helical antenna from Taoglas (TG.22.0111, 824 MHz-2.17 GHz) were used. A carrier frequency of 1.8 GHz and 15 dBm was chosen because it provided the highest signal amplitude using the helical antenna (verified with a spectrum analyzer Siglent SSA3021X and two TG.22.0111). For generating the beat signal, two signal generators were used: a Siglent SSG3000X and a Rohde&Schwarz HM8135. Both signals with amplitude of 15 dBm were superimposed by using an inverted HF beam splitter and then the same helical antenna was used. The resulted signals are presented in Figures 1 a) to d).

In Figure 1 a), the frequency spectrum of a 100% amplitude modulated 1.8 GHz carrier signal with 50 Hz modulation signal is presented. The center of the scale is at 1.8 GHz with 500 Hz span. Clearly, the frequency spacing of 50 Hz between the carrier signal and the sidelobes can be seen. The y-scale is in logarithmic dB scale. The signal generator Siglent SSG3000X also uses higher order sidebands for the amplitude modulation, but already the 2nd order sideband has -15 dB less amplitude. In Figure 1 c), the corresponding envelope of the amplitude modulated signal of a) is presented which was measured with a Rohde&Schwarz RTM3004 oscilloscope. For this measurement, two helical antennas (TG.22.0111) were used which were placed at the same distance as the antenna-seeds distance of the later described measurements in order to get values for the field strength of the

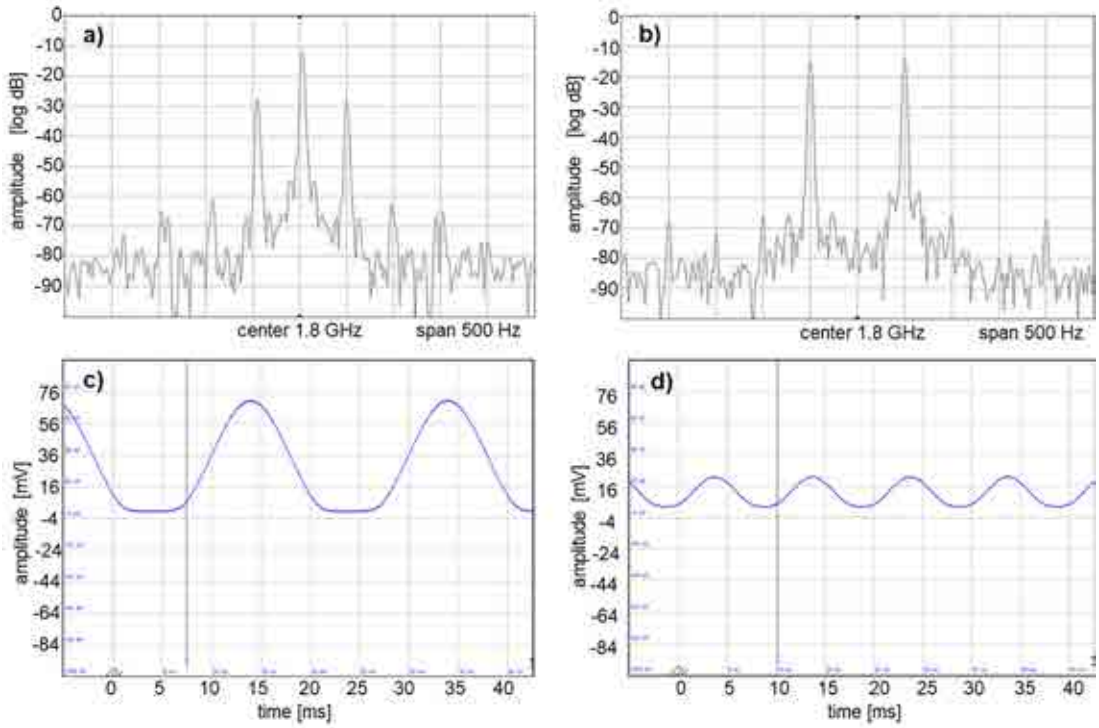

Figure 1: a) Frequency spectrum of the amplitude modulated signal in frequency space with main frequency signal and side lobes. b) Frequency spectrum of the beat signal in frequency space showing that two frequencies of same amplitude are applied. c) Resulting envelope signal of the amplitude modulated signal measured with an oscilloscope with periodicity of 20 ms. d) Resulting envelope signal of the beat signal measured with an oscilloscope with periodicity of 10 ms

applied ELF-EMFs. The maximum amplitude of the amplitude modulated signal in c) is 68 mV. The amplitude loss by detection of the signal with the second helical antenna needs to be taken in account, which is a factor of two different amplitudes as a first order assumption. Therefore, an amplitude of roughly 136 mV of the electric field can be approximated which is acting on the garden cress seeds. The measured periodicity in time in Figure 1c) is 20 ms which correlates well with the ELF-EMF of 50 Hz.

In Figure 1 c), the frequency spectrum of the beat signal is shown. The center of the scale is at 1.8 GHz with 500 Hz span. According to equation (13) a frequency difference of 100 Hz was set at the two signal generators in order to create a beat envelope of 50 Hz. In Figure 1 d) the corresponding envelope measured in the time domain is presented. A periodicity of 10 ms was detected instead of the expected 20 ms which means that the envelope of the created beat signal has a 100 Hz periodicity. The only reasonable explanation is that the inverted HF beam splitter is not leading to a superposition of the HF signals but to a multiplication, which means to equation (3) without the constant factor 1. Still an ELF-EMF can be created by the beating method, but the frequency difference between the two signal generators was needed to be adjusted for the experiments. The detected amplitude of the beat signal by using two helical antennas was approximately 22 mV (see Figure 1 d) which is only one third of the amplitude of the amplitude modulated one. This smaller amplitude is caused by combining the two high-frequency signals from two different signal generators using the inverted HF splitter. The experiments were done in ambient conditions, at constant room temperature and under natural day light. Five to six petri dishes, each with ten garden cress seeds were used in one experimental cycle. The seeds of garden cress were placed onto layers of tissues in a petri dish, as visualized in Figure 2 a). In total, six experimental cycles were conducted. In order to minimize external effects, the petri dishes were kept next to each other and as closely as possible, except for the time when the non-reference ones were treated with the ELF-EMF. A reference petri dish (one for each experimental cycle), where no ELF-EMF was applied, was used for each experimental cycle. The average length of the garden cress was similar for all six reference petri dishes from which it can be concluded that the external conditions were similar for all petri dishes.

Figure 2: a) For each experiment, ten seeds of garden cress were placed next to each other onto water-soaked tissue layers. b) The helical antenna was placed directly above the cress seeds for applying the electromagnetic waves. c) After 100 h of germination and seedling the length of the cress seeds was measured.

The helical antenna was placed directly above the seeds (see Figure 2 b). Just before the start of the experiment, the seeds were soaked with water and then ELF-EMFs were applied for 20 minutes. This ELF-EMF treatment was repeated every 24 hours and after 100 hours the lengths of garden cress seeds were measured (Fig. 2 c). The seeds were kept wet with 12 ml of water each day.

4. Result

As described in the previous chapter, for each experimental cycle one petri dish with seeds was not exposed to ELF-EMFs, serving as references. For four experimental cycles, an amplitude modulated RF signal was used and the different modulation frequencies are listed in the left row of the left part of Table 1. The modulation frequency was set between 1 Hz and 200 Hz. Several modulation frequencies were repeated in the replicated experimental cycles in order to increase the confidence level of the results. In addition, a carrier signal of 1.8 GHz without amplitude modulation was used in the first experimental cycle, resulting in seedling lengths similar to the unexposed references. The carrier signal experimental is placed at the bottom of the left part of Table 1 and is named "$1.8 \cdot 10^{8}$".

The length of the seedlings was measured and the average length for each frequency is listed in the middle row of the table. In the right row, an experimental error is listed. Besides an inaccuracy of length measurement, the error also indicates the measure of how far a set of numbers is spread out from their average value, the variance. Not all cress seedlings in one petri dish have exactly the same length after 100 hours of growth and in order to take the spread into account, the variance was calculated and added to the length measurement inaccuracy.
The average lengths of six references are between 20.6 mm and 26.6 mm. If a shorter or longer average length of the seedling is obtained for certain ELF-EMFs, then these results are worth a more detailed discussion.

The right part of Table 1 presents the ELF-EMF values and results of the two experimental cycles where the ELF-EMF was generated by a beat. Here, the reference and in addition the 50 Hz and 100 Hz ELF-EMF were repeated in order to improve significance and validity of the results. For most ELF-EM frequencies, the results are located within the spread of the references. The only frequency region which shows a significantly different length is around 50 Hz modulation frequency.

This shorter seedling length at 50 Hz is obtained for all experimental cycles and also for both electromagnetic field modulation methods. For the amplitude modulation technique, the length at 50 Hz ELF-EMF is not much shorter than those of the references and could be explained within the measurement error. But for the experiments with the beat signal the resulted average lengths at 50 Hz are below 18 mm and for one cycle even below 15 mm, both outside the reference band.

For the amplitude modulation method, one experiment was done at 50 Hz with a factor 10 lower intensity (5 dBm instead of 15 dBm) and is referred to in Table 1 as "50**". Interestingly, the resulted length of 19.5 mm lies between the reference band and the results at 50 Hz full EMF intensity which provides a first information regarding amplitude dependency.

5. Discussion

This experimental study reveals a retarded growth of garden cress seeds when exposed to an ELF-EMF of 50Hz, either created by the amplitude modulation method or created by a

Amplitude modulation		
frequency [Hz]	length [mm]	error [mm]
Ref	21.6	2.6
Ref	26.6	1.5
Ref	20.6	2.7
Ref	24.4	2.4
1	20.5	2.7
1	24.3	2.7
4	22.8	2.6
7	22.2	3.0
10	22.9	2.5
10	23.2	3.1
10	21.4	2.9
25	23.2	2.2
30	20.9	2.3
50	18.0	2.3
50	19.4	3.0
50	18.6	2.4
50	18.1	2.0
50**	19.5	2.3
70	25.5	2.6
90	21.0	2.4
200	23.1	2.4
$1.8 \cdot 10^9$	25.8	2.4

Beat		
frequency [Hz]	length [mm]	error [mm]
Ref	23.6	2.2
Ref	23.0	2.4
20	22.9	2.3
40	20.1	2.1
50	17.7	2.2
50	14.9	2.4
60	22.9	2.8
100	19.7	2.6
100	23.3	2.2
150	19.4	2.0
200	19.1	2.3

Table 1: Results of the germination and seedling experiments with garden cress under the influence of ELF-EMFs. In the left part of Table 1, the results with an amplitude modulated signal are presented and in the right part the results where a beat signal was applied.

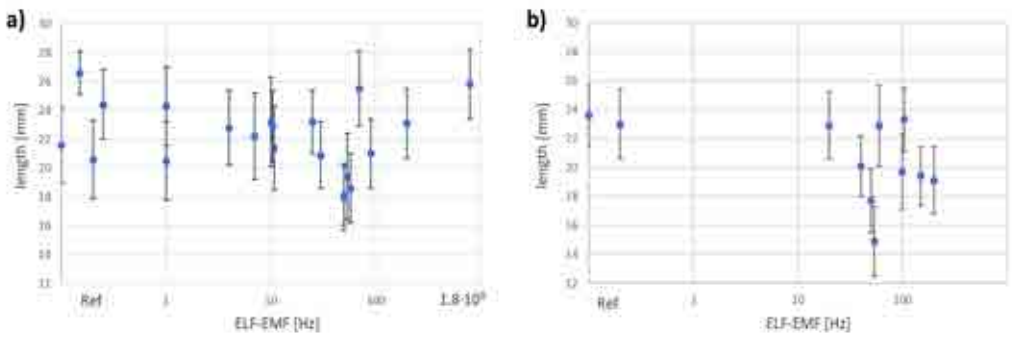

Figure 3: Numbers of Table 1 visualized by graphs: a) the obtained average lengths with using an amplitude modulated signal, and b) the length of the garden cress seedling for an applied beat signal.

beat process. The retarded growth was found to be more pronounced for the beat signal method which has a smaller signal amplitude as presented in Figures 1 c) and d). Both envelopes of the resulting electromagnetic signals are very similar in shape (see Figure 1). Therefore, one can conclude that the growth distinction might be caused by the difference in the frequency domain. Figure 1 a) shows that the amplitude modulated signal by one signal generator consists of the carrier frequency (in this experiment 1.8 GHz) and side lobes caused by the multiplication of the carrier signal with the modulation signal (50 Hz in Figure 1a). Therefore, the first order side lobes are at 1.799 999 950 GHz and 1.800 000 050 GHz. Whereas Figure 1 b) presents that the beat signal consists of only two frequency contributions (1.799 999 950 GHz and 1.800 000 050 GHz in Fig. 1 b) which have the same amplitude in order to create a beat signal.

As introduced in the beginning, one way of explaining the effect of the ELF-EMF on living organism is the concept of forced oscillation. For the resonant case, the frequency of the driving force needs to be similar to the eigenfrequency of the biological system. When an RF signal is used as a carrier signal, this RF frequency itself is

too high for the creation of a resonant condition. Therefore, a low-frequency signal is added, either by using an amplitude modulation method or by creating a beat signal. In the case of the amplitude modulation, this low-frequency signal is the difference between the carrier signal and the side lobes (see Figure 1 a). There are at least three frequencies involved: the carrier signal, the lower side lobe und the upper side lobe. The frequency difference between these three signals is +50 Hz and -50 Hz for Figure 1 a). In the case of the beat signal, there are only two signals of equal amplitude involved as depicted in Figure 1 b). There exists a more defined frequency difference between two signals. This clearer definition of a frequency difference might lead to a better forced oscillation in the plants than in the case of an amplitude modulation. But this assumption needs to be proved in future work.

Both an increase and decrease of the germination and seedling properties of plants under the influence of ELF magnetic fields have been reported [8,9]. Especially in [8], the strongest decrease of seedlings was found for 50 Hz ELF magnetic field treatment. It was assumed that this change of growth might result from the excitation of Ca^{2+} ions. This is an explanation which often is used to explain results obtained with ELF-EMFs (see Reference [15] and references therein). Calcium is an essential structural, metabolic and signalling element in plants and it is involved in many cellular processes such as cell proliferation. It is transported in Ca^{2+}-permeable ion channels. These voltage-gated channels are normally closed, but they open in response to a transmembrane voltage pulse. Therefore, the influence of an ELF-EMF on the Ca^{2+} membrane channels might be a stimulation of the Ca^{2+} transport across the membrane channels and thus altering the growth characteristic of the plants. Due to the fact that we only detect a retarded growth for exactly one modulation frequency, one can conclude that this ELF-EMF of 50 Hz resonantly stimulates the calcium transport by a forced oscillation.

There exist many papers about the influence of 50 Hz, respectively 60 Hz electromagnetic fields on the healthiness of humans and other living creatures because this is the frequency of our power lines (see for example [16–19]). According to Maxwell's equation, every current is generating a magnetic field and therefore the currents in our power lines are also creating small magnetic fields of 50 Hz, respectively 60 Hz frequency. But following the explanation using forced oscillations by ELF-EMF, we think that it is a pure random coincidence that here the garden cress seeds are showing the strongest effect also at 50 Hz ELF-EMF. Because it cannot be assumed that the cells and calcium channels in garden cress seeds have the same eigenfrequencies as human body cells and therefore there should be no correlation between these two topics.

6. Conclusion

In conclusion, we have introduced a new method of creating an ELF-EMF by superimposing two GHz electromagnetic waves of very similar frequencies. This beating concept if of course not new in general and it is applied in many different technical applications but to our knowledge, it has not been used yet for the creation of ELF-EMFs. These ELF-EMFs created by a beating process and additionally by using a standard amplitude modulation technique were used to alter the germination and seedling behavior of garden cress seeds. A retarded growth for an ELF-EMF of 50 Hz was found. This frequency seems to resonantly influence the growth of the plant because it is the only frequency where a retarded growth was detected. Hereby, the beating signal has shown an even bigger effect than the amplitude modulated signal which opens up new possibilities for influencing the proliferation of bacteria or even human body cells, which will be addressed in future work.

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AI in Cosmetics. Determinants Influencing the Acceptance of Product Configurators.

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ABSTRACT

AI revolutionizes the cosmetics industry through innovative and digital personalization and advanced customer advice. AI-based product configurators enable individualization for customers and promote competitive advantages for companies. The acceptance of AI-based product configurators in the cosmetics industry has not been sufficiently researched. To fill this research gap, a quantitative study was conducted through a convenience sample of 116 female subjects. Ten hypotheses were used to investigate which determinants influence technology acceptance. This research showed that the age of the female customers has a significant influence on usage intention, perceived enjoyment and self-efficacy. The determinants subjective norm, personal image, and perceived ease of use significantly influence technology acceptance. The study provides added value for future adaptations of sales processes regarding digital ordering algorithms and product configurators along the customer journey.

Künstliche Intelligenz (KI) revolutioniert die Kosmetikindustrie durch innovative Personalisierung und erweiterte Kundenberatung. KI-basierte Produktkonfiguratoren ermöglichen Individualisierung für Kunden und fördern Wettbewerbsvorteile für Unternehmen. Die Akzeptanz von KI-basierten Produktkonfiguratoren in der Kosmetikindustrie ist noch nicht ausreichend erforscht. Um diese Forschungslücke zu schließen, wurde eine quantitative Studie mit einer Convenience-Stichprobe von 116 weiblichen Probanden durchgeführt. Anhand von zehn Hypothesen wurde untersucht, welche Determinanten die Technologieakzeptanz beeinflussen. Die Untersuchung zeigte, dass das Alter der Kundinnen einen signifikanten Einfluss auf die Nutzungsabsicht, den wahrgenommenen Genuss und die Selbstwirksamkeit hat. Die Determinanten subjektive Norm, persönliches Image und wahrgenommene Benutzerfreundlichkeit beeinflussen die Technologieakzeptanz signifikant. Die Studie liefert einen Mehrwert für zukünftige Anpassungen von Verkaufsprozessen hinsichtlich digitaler Bestellalgorithmen und Produktkonfiguratoren entlang der Customer Journey.

KEYWORDS

Artificial intelligence (AI), cosmetics industry, product configurators, technology acceptance, customer consultation

Künstliche Intelligenz (KI), Kosmetikindustrie, Produktkonfiguratoren, Technologieakzeptanz, Kundenberatung

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1. Introduction

The cosmetics industry continues to grow with the increasing introduction of new products. With global sales of $250 billion in 2018 (Hudson, Kim, and Moulton 2018), the cosmetics industry has grown steadily since then and is currently estimated to be worth around $472.8 billion, according to Consumer Markets Research (Beauty & Personal Care – Worldwide 2022). A large part of the success of the cosmetics industry can be attributed to brand names, the lifestyle the brand represents or the luxury it conveys. Individuality is suggested in the form of numerous line extensions of existing standard products. In order to meet the trend and the expectations of consumers for individual and personalized products, cosmetics companies are increasingly focusing not only on personalized recommendations but also on product variants tailored to the individual needs of each customer in a mass market (Gyan Research and Analytics 2018). The success of the entire customer experience, from wanting a solution through a product, to searching for it, to the ordering experience, to product usage, might significantly improve through the use of well-designed digital ordering algorithms and product configurators (Franke and Piller 2004). AI-based product configurators offer the cosmetics and beauty industry the opportunity for mass customization (Rainsberger 2021; Wabia 2020).

This paper investigates whether the technology acceptance study by Cengiz et al. (2020) can be transferred to the German cosmetics market for women within different age groups since no research results are available here (Davis, Bagozzi, and Warshaw 1989; Grosso, Forza, and Trentin 2017; Walczak, Kellogg, and Gregg 2010). Subsequently it is necessary to investigate which different factors influence the usage behavior of AI-based product configurators in the cosmetics industry and how these factors can be interpreted. Although cosmetic products can be consumed across genders, this study focuses on the female target group. The interest of the female target group in decorative cosmetics increased by 15% from 2013 to 2018. Female customers purchased 40% more decorative cosmetics than male customers during the period (GIK 2019). To analyze these aspects, two different female age groups representing the target groups (GIK 2019) of the cosmetics industry were interviewed with a convenience sample method about their usage behavior with AI-based product configurators as well as their perceived usefulness and sensed usability of such tools.

The paper is organized as follows. Section 2 reviews the theoretical background of AI and AI-based product configurators in relation to the cosmetics industry. Section 3 describes the research framework and hypotheses; Section 4 discusses the research design and technology acceptance model (TAM) 3 research methodology; Section 5 presents the results; Section 6 concludes with recommendations for the use of AI-based product configurators in a female target group and identifies opportunities for further research as well as the limitations of this work.

2. Theoretical Background

Artificial intelligence is an established part in the cosmetics industry and changes the way products are offered and the interaction with customers (Mangtani et al. 2020). The megatrend of individualization promotes the development of individualized products and services in the beauty industry (Rainsberger 2021)

Artificial intelligence

According to Rainsberger (Rainsberger 2021), AI is about processes in which machines learn how to learn. As a sub-field of computer science, AI is used to identify intelligent behavior and it imitates human intelligence (Hartmann 2018). A distinction is often made between soft and strong AI. Soft AI applications can analyze data to make predictions and support human-based tasks (Buxmann 2018). Strong AI has the ability to solve tasks intellectually on its own, as humans do. Strong AI does not yet exist (Paschen et al. 2020).

The development of AI applications will continue to increase. This is due to some key indicators: Computing capacity, high communication speed and expanded storage capacity, better algorithms and decreasing prices for them (J. Paschen, Wilson and Ferreira 2020). The combination of machine accuracy with human mental connections, emotions and creativity enables deep customer understanding along the entire customer journey, which can lead to competitive advantages in sales. (Rainsberger 2021)

Product configurators

Product configurators are an instrument of mass customization as they provide customers with the possibility to individually adapt products and at the same time, the company is benefiting from the scalability of the system (Davis, Bagozzi, and Warshaw 1989; Wabia 2020). Examples of product configurators range from the self-configuration of a car to a menu in a fast-food restaurant. Product configurators can be differentiated into five appearances according to their capabilities. Select-to-order (STO) configurators let customers choose from the standard range of a product. There is no dependency between the characteristics of the product and its availability, so that any products and variants such as colours can be combined here. This is the simplest form of product configuration (Henseler 2004; Lutz 2012). Pick-to-order (PTO) configurators are integrated in many online shops. The configuration options are additions and extensions to the already constructed product. Customers can add their individual preferences (Henseler 2004; Lutz 2012). For more extensive configurations, configure-to-order (CTO) configurators are used. Many combinations can be selected, leading to extensive product variations. To create a meaningful product, a relationship logic is required due to the dependency of the components. Individual options are added automatically to maintain functionality (Henseler 2004; Lutz 2012). This form of configurator is often used by both staff and customers for visualization. The CTO configurator is normally used as a configurator whose configured end product is only manufactured after the customer's preferences have been finalized. For customized products, specific parameters can be defined through the make-to-order (MTO) configurator. Manufacturing of the product begins as soon as the customer order is received (Henseler 2004; Lutz 2011). The visualizations of custom-made products in a configurator serve the purpose of individualization and should function in a customer-centric way. Finally, engineer-to-order (ETO) configurators promote the development of new products or product components. The configurations are done by experts and are used for the purpose of cost verification, handling, and functionality. In the following, product configurators are defined as pick-to-order configurators. The manifestations of product configurators can be empowered with soft AI.

AI-based product configurators learn continuously by searching for new solutions, based on data which they perceive and analyze changes in the environment and derive conclusions from that (Rainsberger 2021). One example of this is that customers can use configurators to influence the final product and, likewise, companies can use these customer requirements to directly modify products according to customer specifications (Lutz 2011). By systematizing the offer, the sales process is accelerated and relieved and costs can be reduced as a result (Kortmann, Klink, and Wüpping 2009). By combining different components within a product configurator, the product range can be expanded without changing or adapting internal processes (Kortmann, Klink, and Wüpping 2009).

By using AI-based product configurations, the customer receives products that exactly match their expectations and requirements (Helo 2006). As a result, customers get individualized products that fit them perfectly delivered to their homes without the need for face-to-face consultation. This is therefore beneficial to an increase in trust thus actively contributing to customer loyalty (Rainsberger 2021). Companies benefit from the AI-based collection and analysis of data in that they gain valuable insights into the moods, motives and behavior patterns of customers and can thus develop better-tailored products. Customers benefit from the shift from product-based offerings to customer experience-based models (Mangtani et al. 2020).

AI-based product configurators in the cosmetics industry

AI-based product configurators offer opportunities for the cosmetics industry in terms of higher shopping cart values, customer loyalty, and the intensification of customer relationships through customized digital advice (Hedin, Ohlsson, and McKenna 1998; Wabia 2020). Research on product configurators and mass customization has shown that consumers are willing to pay a significant premium to purchase some configured products, e.g., in the premium jewellery and fashion sectors, if they perceive the configuration process positively (Franke and Piller 2004; Grosso, Forza, and Trentin 2017; Wabia 2020). The main problem with this technique is that there are different preferences regarding technology acceptance,

trust and willingness to pay for configured products depending on nationality, age or gender and the product (Wabia 2020). The research of Cengiz et al. (Cengiz and Bakırtaş 2020), Holden (Holden and Rada 2011) and Venkatesh and Bala (Venkatesh and Bala 2008) provides an indication that it is necessary to pick up the target group at its level of technical knowledge.

AI-based (PTO) product configurators are already used in the market and can be classified as an instrument of mass customization (Rogoll and Piller 2004). Artificial intelligence-based solutions within the cosmetics industry can be found in applications like quiz-based models, where customers can choose from different answer options, as well as chatbots and special DNA-based AI applications, for example, to receive individual skin and hair treatment recommendations (Rainsberger 2021).

One of the main uses of AI-based product configurators in the cosmetics industry are applications that analyze the condition and needs of the skin and can be characterized as PTO configurators or according to Helo (Helo 2006) as feature-based configuration. A practical example shown in this research is the skin analysis tool "Skin Advisor" by Olay of the Procter & Gamble group (“Olay Skin Advisor” 2022).

The process of Olay's skin analysis tool is as follows: The potential Olay customer takes a selfie after starting the analysis. The following text appears to bridge the waiting time:

"Thank you for your selfie! The following is analysed: Your 5 zones of skin ageing will be analysed." The customer then answers questions about their beauty routine in an online questionnaire and can choose answers from a series of multiple-choice questions. Exemplary questions included: "What concerns you most about your skin?"; "What is your main concern?" (related to the previous question); "What is your skin type?"; "What products do you use at least twice a week?". The image material is evaluated in the backend of the system with the answers and customer preferences and simultaneously matched with Olay's products. The frontend then outputs the skin age as a result, with corresponding product recommendations.
The recommendations can be customized according to preference. For each product, it is indicated which of the skin problems it is supposed to solve. The suggested products can be added directly to the shopping cart (Olay Skin Advisor 2022).

3. Research framework

As the current state of research shows, the question about the influence of AI-based product configurators on different female age groups in the German cosmetics industry could not be answered. To be able to determine differences in the usage behavior depending on age, the participants were divided into two age groups "0–49 years" and "older than 50 years".

As part of the investigation into the usage behavior of customers, the first hypothesis measured perceived enjoyment (ENJ) and usage intension (UI) within the age groups.

(H1a) Younger costumers perceive higher enjoyment in using AI-based product configurators than older costumers.

(H1b) Younger customers are more likely to use AI-based product configurators than older customers.

In the second hypothesis, computer self-efficacy (CSE) and computer anxiety (CANX) were measured. It was investigated whether there is a possible correlation between age and computer self-efficacy and computer anxiety.

(H2a) Older customers feel less computer self-efficacy using AI-based product configurators than younger customers.

(H2b) Older customers have higher concerns about using AI-based product configurators than younger customers.

Furthermore, the third hypothesis investigates whether there is a correlation between the acceptance of AI-based product configurators and subjective norm (SN) as well as objective usability (OU). The hypothesis proceeds from the proposition that such product configurators will be used more frequently if there is acceptance of them in the customer's social environment.

(H3) The more accepted AI-based product configurators are in the personal social environment, the higher the objective usability of the customer.

The fourth hypothesis relates perceived ease of use (PEOU) to perceived usefulness (PU) and predicts that perceived ease of use positively influences perceived usefulness.

(H4) The greater the perceived ease of use of the AI-based product configurator, the higher the perceived usefulness is rated.

The next hypothesis deals with the awareness of external control (PEC) and the traceability of the results (RES). It implies that younger customers are more likely to have the necessary skills and technical resources to use an AI-based product configurator, are more likely to get the required information and are aware of the limitations of such product configurators.

(H5a) Younger customers have a higher perception of external control of an AI-based product configurator than older customers.

(H5b) Younger customers comprehend the results of an AI-based product configurator better than older customers.

The personal image, which indicates the degree of self-identification with AI-based product configurators, is also associated with usage. The purpose of the sixth hypothesis is to find out whether one's image (IMG) influences purchasing relevance (REL).

(H6) The more the personal image matches the use of an AI-based product configurator, the more likely it is to become relevant for purchasing.

The last hypothesis focuses on the correlation between the output quality (OUT) of an AI-based product configurator and the enjoyment of using new technologies (ENJ). It relates output to the resulting use of new technologies.

(H7) The better the output quality of an AI-based product configurator, the more likely it is to enjoy the use of this technology.

To prove these hypotheses for innovative technologies such as AI-based product configurators, validated items from the TAM3 technology acceptance model (Venkatesh 2000) were used, as shown in Table 1 in the appendix. These were slightly adapted to the topic of customer usage behaviour towards AI-based product configurators. Voluntariness (VOL) according to Moore and Benbasat (Moore and Benbasat 1991) was not considered in this study, as it is assumed that the use of AI-based product configurator is voluntary (Venkatesh 2000). The research design allows the usage data to be collected separately from its determinants, such as perceived usefulness and perceived ease of use.

4. Research design

This survey was developed based on Curwin and Slater's ordinal rating scale (Curwin, Eadson, and Slater 2002) and following the TAM3 by Venkatesh and Bala (Venkatesh and Bala 2008). The methodology and evaluation are a replication of Cengiz et al. (Cengiz et al. 2020). It was created via an online survey tool. Participants in the survey were selected using a random sample within the female age groups "0–49 years" and "older than 50 years". To assess the participants' level of knowledge, two questions about knowledge and use were asked in advance. A total of 116 female respondents, which corresponds to a response rate of 73.89%, took part in the survey on the usage behavior of customers towards AI-based product configurators in the cosmetics industry.

In order to be able to make qualitative statements and to avoid selection bias, the participants from the convenience sample were matched with the basic population of the cosmetics industry and the age structure. The Appendix contains a detailed breakdown of the selected variables including the respective items with which they were measured. The questionnaire used Likert scales with a rating range of 1 (strongly disagree) to 7 (strongly agree).

In the context of this paper, the participants of the conducted survey were shown the function of an artificially intelligent product configurator with the help of the Skin Advisor of the cosmetics brand Olay (2021), which is described in chapter 2. In order to test the hypotheses, a t-test was performed for each case, using a 95% confidence level for all tests of statistical significance. The t-test is a statistical technique that assesses whether there is a significant difference between two groups, as in the between-subjects design of this study, by comparing their mean values for a particular variable specified by the corresponding hypothesis. A higher absolute t-value indicates a more significant difference between the mean values of the two groups. A sufficiently high absolute t-value can support

the acceptance of the hypothesis with a certain level of confidence (Cengiz et al. 2020).

5. Findings

Of the 116 respondents, 73.3% are in the age group between 0 and 49 years and 26.7% are in the age group "older than 50". 41 participants in the 0–49 years' age group have already used an AI-based product configurator, while 27 participants in the over 50 age group have used a configurator. The first queries show that the younger age group has already used an AI-based product configurator more frequently than the over 50s.

t-tests were performed to test the hypotheses. The results were interpreted depending on the Levene's test. The results of the investigated 10 hypotheses are presented in numerical order.

(H1a) Younger costumers perceive higher enjoyment in using AI-based product configurators than the older costumers.

(H1b) Younger customers are more likely to use AI-based product configurators than older customers.

For ENJ, the age group under 49 has a mean of 4.6, and those over 50 have a mean of 3.5. For UI, the mean values within the age groups are identical to ENJ. The Levene's test for ENJ is significant, so there is no homogeneity of variance. Welch's t-test for unequal variances shows (Table 1) that there is a significant difference between age groups for ENJ (t (45,49) = 4,01, p < 0.001, CI 95% 0.56983–1.67988). The younger customers have a significantly perceived higher enjoyment in using AI-based product configurators than the older costumers. H1a is accepted.

The Levene's test for equal variance is not significant in UI and indicates homogeneity of variance. The results of the t-test show a significant difference between the age groups regarding UI (t (114) = 3,80, p < 0.001, CI 95% 0.49979–1.59148). This indicates that younger customers have a significantly higher usage intention than older customers. Therefore, H1b is accepted.

(H2a) Older customers feel less computer self-efficacy using AI-based product configurators than younger customers.

(H2b) Older customers have higher concerns about using AI-based product configurators than younger customers.

For CSE, the age group under 49 has a mean of 5.3, and those over 50 have a mean of 4.3. For CANX, the mean value of the younger age group is 3,3 and that of the older customers is 3,9. The Levene's test is not significant for CSE and CANX. Variance homogeneity can be assumed. The results of the t-test (Table 2) show that younger customers have significantly higher computer self-efficacy than the older customers (t (114) =4,354, p < 0.001, CI 95% 0.54959–1.46730). Therefore, H2a is accepted. If the parameter of computer anxiety is considered, it can also be observed that the younger customers are significantly less afraid of using a computer than the older age group (t (114) = -3.672, p < 0.001, CI 95% -0.94005 to -0.28121). H2b is accepted.

Independent Sample Test

		Levene´s Test for Equality of Variances		*t-test for Equality of Means*					*95% Confidence Interval of Difference*	
		F	*Sig.*	*t*	*df*	*Sig. 2-tailed)*	*Mean Difference*	*Std. Error Difference*	*Lower*	*Upper*
Usage Intention (UI)	Equal variances assumed	2,192	0,141	3,785	114	<0,001	1,04564	0,27554	0,49979	1,59148
	Equal variances not assumed			3,549	47,413	0,001	1,04564	0,29461	0,45309	1,63819
Percieved Enjoyment (ENJ)	Equal variances assumed	4,734	0,032	4,479	114	<0,001	1,12486	0,25113	0,62736	1,62235
	Equal variances not assumed			4,081	45,482	<0,001	1,12486	0,27565	0,56983	1,67988

Table 1: Performed t-test for usage intention (UI) and perceived enjoyment (ENJ).

Independent Sample Test										
		Levene´s Test for Equality of Variances					*t-test for Equality of Means*		*95% Confidence Interval of Difference*	
		F	*Sig.*	*t*	*df*	*Sig. 2-tailed)*	*Mean Difference*	*Std. Error Difference*	*Lower*	*Upper*
Self-Efficacy CSE))	Equal variances assumed	2,262	0,135	4,354	114	<0,001	1,00844	0,23163	0,54959	1,46730
	Equal variances not assumed			4,633	60,435	<0,001	1,00844	0,21768	0,57309	1,44380
Computer Anxiety (CANX)	Equal variances assumed	2,323	0,130	-3,672	114	<0,001	-0,61063	0,16629	-0,94005	-0,28121
	Equal variances not assumed			-3,319	44,924	<0,001	-0,61063	0,18401	-0,98125	-0,24000

Table 2: Performed t-test for computer self-efficacy (CSE) and computer anxiety (CANX).

(H3) The more accepted AI-based product configurators are in the personal social environment, the higher the objective usability of the customer.

If the two parameters subjective norm (SN) and objective usability (OU) are differentiated, it can be seen that OU is distributed relatively normally, with a slight shift to the right and one outlier. SN is distributed with a few outliers. Figure 1 shows the positive linear relationship of OU and SN with $R^2 = 0,252$.

To determine whether there is a significant correlation, a t-test was conducted. Two groups were formed of SN. The middle (value 4) was chosen as the boundary between the two groups. All values greater than or equal to 4 are on the right side of the Likert scale (4 = partially agree/ disagree to 7 = absolutely agree) and belong to group 1. All values less than 4 are on the left side of the Likert scale (3 = rather disagree to 1 = absolutely disagree) and belong to group 2. It is important to mention here that the two variables were examined for their difference and dependence independently of the age groups.

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Group 1, with measurements greater than or equal to 4, resulted in higher values (N = 82; Mean = 5.5; Std. Dev. = 0.89096) than Group 2, with measurements less than 4 of the second item SN (N = 34; Mean = 4.7; Std. Dev. = 1.02606). This difference could thus be proven to be significant ($t(114) = 3.862$; $p < 0.001$, CI 95% 0,3578–1,11085) and the formulated H3 can be accepted. It can now be concluded that the more an AI-based product configurator is accepted in the personal social environment, the higher the objective usability. Objective usability here means that the respondents tend to believe that AI-based product configurators will be used more in sales in the future, that there will be an increasing number of users of AI-based product configurators.

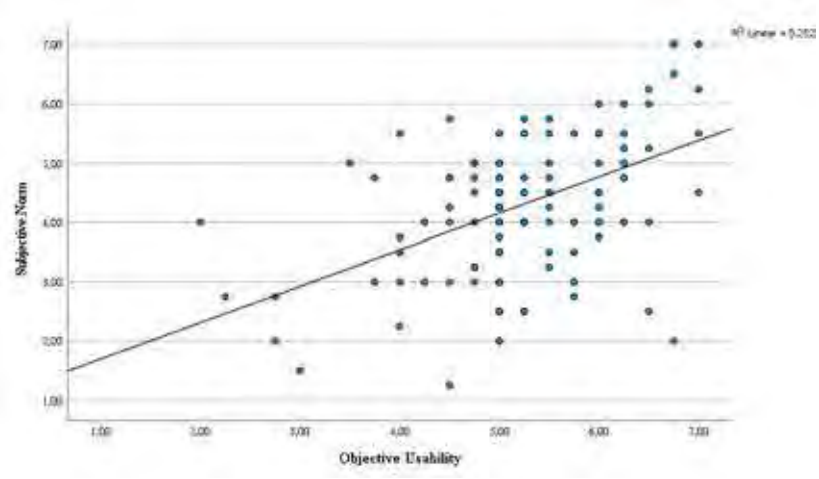

Figure 1: Scatter plot of the variables OU and SN.

(H4) The greater the perceived ease of use of the AI-based product configurator, the higher the perceived usefulness is rated.

To test and illustrate the correlation of perceived ease of use (PEOU) and perceived useful-ness (PU), a significant difference is to be demonstrated using the t-test. First, both variables are considered individually. PU shows a slightly right-skewed distribution. PEOU shows a right-sloping distribution. This indicates that the majority of participants consider an AI-based product configurator to be user-friendly and the opinion on the perceived usefulness of such a product configurator is more positive than negative. Figure 2 shows the positive linear relationship of PEOU and PU with $R^2 = 0{,}587$.

After establishing the null hypothesis, the two variables PEOU and PU were tested by means of a t-test. As described in hypothesis 3, the 7-point Likert scale was again divided into groups 1 and 2. In group 1 (PEOU), higher values (N = 99; Mean = 4.6894; Std. Dev. = 0.71615) were detected than in group 2 (N = 17; Mean = 3.0735; Std. Dev. = 0.68900). This difference was demonstrated to be significant (t (114) = 8.640; $p < 0.001$, CI 95% 1.245–1.986). It can therefore be concluded that there is a correlation between PEOU, and PU. It can be said that the higher the PEOU of an artificially intelligent product configurator, the better its PU is rated. Therefore, H4 can be accepted.

To test H5a and H5b, age groups were related to perceptions of external control (PEC) and the result traceability (RES) and analyzed with the help of a t-test (Table 3).

(H5a) Younger customers have a higher perception of external control of an AI-based product configurator than older customers.

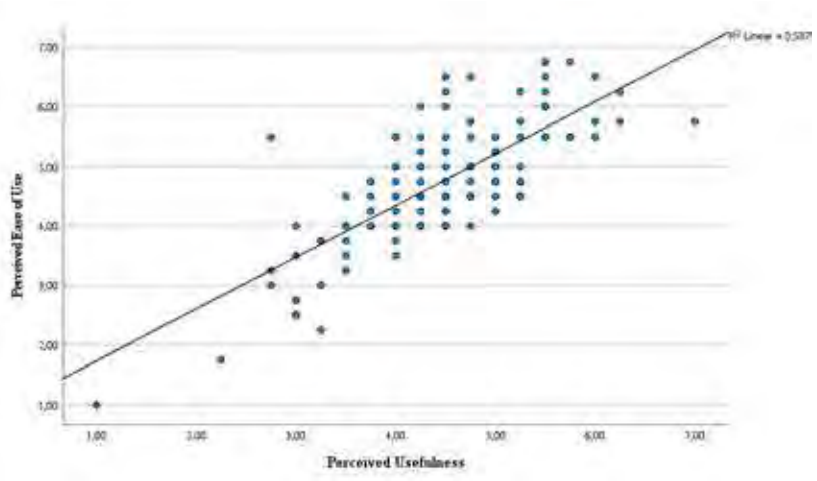

Figure 2: Scatter plot of the variables PEOU and PU.

Independent Sample Test

		Levene´s Test for Equality of Variances		*t-test for Equality of Means*					*95% Confidence Interval of Difference*	
		F	*Sig.*	*t*	*df*	*Sig. 2-tailed)*	*Mean Difference*	*Std. Error Difference*	*Lower*	*Upper*
Perceptions of External Control (PEC)	Equal variances assumed	5,0334	0,027	4,231	114	<0,001	0,93482	0,22093	0,49716	1,37248
	Equal variances not assumed			3,704	42,878	<0,001	0,93482	0,25241	0,42575	1,44389
Result Traceability (RES)	Equal variances assumed	0,129	0,720	1,732	114	0,086	0,30672	0,17705	-0,04403	0,65746
	Equal variances not assumed			1,682	50,560	0,099	0,30672	0,182302	-0,05935	0,67278

Table 3: Performed t-test for perceptions of external control (PEC) and the result traceability (RES).

(H5b) Younger customers comprehend the results of an AI-based product configurator better than older customers.

After the null hypothesis was formed, the two variables PEC and RES were each tested for the significant difference in relation to the age groups.

Higher values for the perception of external control (N = 85; Mean = 5.5235; Std. Dev. = 0.95869) were observed in the younger group than in the group "older than 50" (N = 31; Mean = 4.5887; Std. Dev. = 1.28054). The Levene's test for PEC is significant, so there is no homogeneity of variance. Therefore, we use the Welch's t-test for unequal variances (Table 3). There is a significant difference between age groups for PEC (t (42,89) = 3,704; p < 0.001, CI 95% 0,42575–1,44389). The younger customers have a significantly perceived higher enjoyment in using AI-based product configurators than the older costumers. H5a is accepted.

No significant difference was found for RES with respect to age groups (t (114) = 1.732, p = 0.086, CI 95% -0.04403–0.65746). The results show that both young and old customers feel identical about the result traceability. Both groups tend to have difficulties telling others about the results of using an AI-based product configurator and thus to trace the results. Therefore, we reject H5b. Thus, it cannot be said that the result traceability of an AI-based product configurator in the cosmetics industry is dependent on age.

(H6) The more the personal image matches the use of an AI-based product configurator, the more likely it is to become relevant for purchasing.

To test this hypothesis, the variables image (IMG) and purchasing relevance (PR) were validated as to whether there is a significant correlation between the own image and the purchasing relevance. Both variables are normally distributed. Figure 2 shows the positive linear relationship of IMG and PR with $R^2 = 0{,}732$.

As for hypotheses 3a, 3b and 4, the results of the seven-point Likert scale were divided into two groups to conduct the t-test. The middle (value 4) was chosen as the cut-off point of the groups. All values of IMG greater than or equal to 4 belong to group 1. All values less than 4 belong to group 2.

In group 1, higher values (N = 59; Mean = 5.4407; Std. Dev. = 0.82511) were found than in group 2 (N = 57; Mean = 3.7222; Std. Dev. = 1.04669). This difference is proven to be significant (t (114) = 9.838, p<0.001, CI 95% 1,37246-2,06602).

From these results, the following conclusion can be drawn. Customers for whom the use of an AI-based product configurator corresponds to the perception of themselves, their values, and their personalities are more likely to think that AI-based product configurators are relevant, attractive, useful, and helpful for the purchase of products in the cosmetics industry. According to the results of the t-test, one's own image influences the customer's purchasing relevance when using an artificially intelligent product configurator in the cosmetics industry.

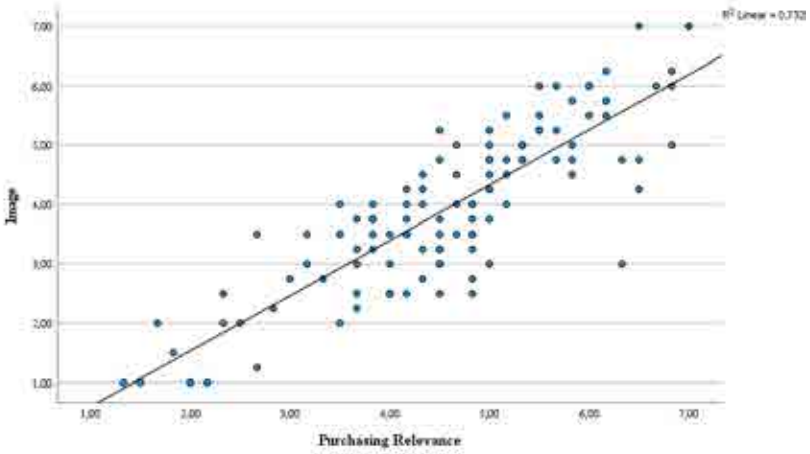

Figure 3: Scatter plot of the variables IMG and PR.

Therefore, hypothesis H6 is accepted.

(H7) The better the output quality of an AI-based product configurator, the more likely it is to enjoy the use of this technology.

The correlation between the variables output quality (OUT) and computer playfulness (CPLAY) is shown below. By looking at the variables individually, both variables are rather normally distributed. Figure 3 shows the relationship of OUT and CPLAY with $R^2 = 0{,}045$.

Again, two groups were formed based on the Likert scale. The two variables were examined for their difference and dependence independently of the age groups. In this case, group 1 with scores greater than or equal to 4 had similar scores (N = 79; mean = 4.2753; Std. Dev. = 0.75595) as group 2 with scores less than 4 (N = 37; mean = 4.0608; Std. Dev. = 0.70318). As was hypothesized after viewing the scatterplot and the low R^2, no significant relationship was found between output quality and enjoyment of computer play (t (114) = 1.456; p = 0.148, CI 95% -0,07741–0,50642). The analysis shows that the quality of the results of an AI-based product configurator does not influence and has no correlation to the customer's enjoyment of using such new technologies. As a result of the knowledge gained from the t-test, hypothesis H7 is rejected.

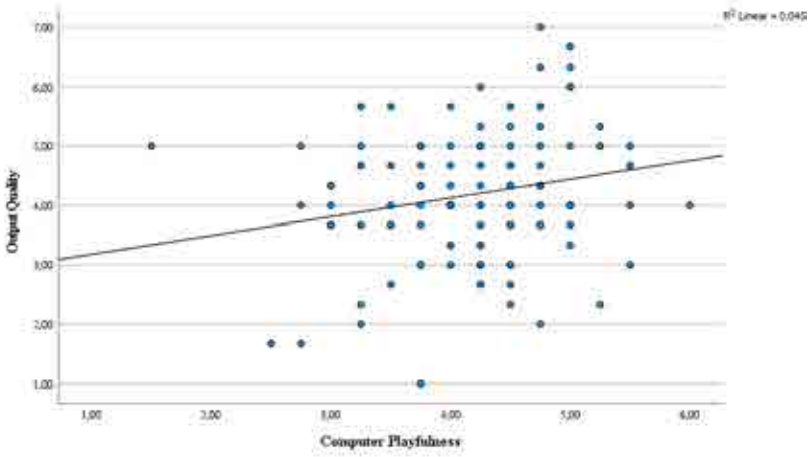

Figure 4: Scatter plot of the variables IMG and PR.

6. Discussion, limitations and conclusion

The technology acceptance and usage behavior of AI-based product configurators has not yet been investigated. This kind of applications is already in use in German cosmetics industry, as previous hurdles, e.g. storage capacity and costs are falling (Paschen, Wilson, and Ferreira 2020). Especially in the field of decorating cosmetics a large market potential can be seen (GIK 2019). However, when using product configurators, the focus should be on the users. Previous research work, e.g. by Venkatesh and Bala (Venkatesh and Bala 2008) has shown that the age of the target group is a decisive factor for acceptance of the benefits. This research shows the potential validity of some of the findings of Venkatesh and Bala (Venkatesh and Bala 2008) for the German cosmetics industry and the use of AI-based product configurators. Thus, of the ten hypotheses, eight were confirmed, and two were refuted.

In particular, the acceptance of hypotheses H1a and H1b showed that age is an important factor in terms of intention to use and perceived enjoyment. Consistent with this, hypothesis tests of H2a and H2b showed that older customers have lower self-efficacy regarding the use of computers and concurrent higher concerns about using AI-based product configurators. Other variables influencing the acceptance of product configurators that were found to be significant in the study were subjective norm and objective usability examined in H3a and H3b. Hypothesis H4 shows that the more user-friendly female participants perceive an AI-based product configurator to be, the more likely they are to perceive it as useful. In this context, the results

of H5a and H5b regarding traceability and perceived external control seem plausible. Here, it was found that both age groups studied had problems comprehending the outcome of an AI-based product configurator. A significant result could also be demonstrated with respect to H6. It was shown that the customer's own image, the degree of self-identification with AI-based product configurators, influences the customer's purchase relevance when using an AI-based product configurator in the cosmetics industry. H7 investigated whether there is a relationship between the expected output quality of the configuration result and the enjoyment of using AI-based product configurators. No significant relationship could be demonstrated. In conclusion, the study shows that age has a significant effect on the acceptance of AI-based product configurators. The significant effect is supported by a positive subjective norm, perceived ease of use, and personal image.

Although the results of this work contribute to the current state of technology acceptance research by using a real-world use case of AI-based product configurators in the cosmetics industry (Olay Skin Configurators) to explore ten hypotheses, there are some limitations in this study that need to be considered. Since the respondents are all female, the outcomes could not be easily transferred in case of other target groups and industries. The sample participants were composed of different groups, but corresponded to the criteria, which in turn were known by the research-team. The division of age into two groups and the nature of the sample limit the interpretation of the results. By selecting the criteria, representativeness in terms of content can be assumed; a calculable mathematical-statistical representativeness or an objectively comprehensible selection procedure should be aimed for in further research. Furthermore, it would be interesting to see the results of a MANOVA test that might complement the results of dividing the data into age groups. In addition, the presented use case is a PTO configurator, so the validity in relation to other product configurators, e.g. ETO, is not guaranteed. It should be noted that, as in Venkatesh and Bala (Venkatesh and Bala 2008), only screenshots were shown to the respondents, leaving the impact of a real interaction with AI-based product configurators undetected.

Ideally, it would be interesting to see if the same results hold true in another industry or country. Future research should also address how the implications of this study can be mapped to in a corresponding customer journey and how this can influence sales revenue streams.

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Mara Roschmann, Daniela Seibel, Katharina Kill & Pearl Heppler

are students pursuing the Master of Advanced Management program at the University of Applied Sciences Neu-Ulm, Germany. As part of their studies, they collaborated and made valuable contributions to this journal paper.

sind Studierende des „Master of Advanced Managements“ an der Hochschule Neu-Ulm. Im Rahmen ihres Studiums haben sie gemeinsam an diesem Journal-Paper mitgearbeitet.

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Inpatient Caregivers' Perceptions of the Use of Passive Exoskeletons in Daily Work – A Case Study

Lukas Schmidbauer*

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ABSTRACT

Background: Nurses in inpatient care are affected by heavy physical activities in their daily recurring working tasks. This includes transferring persons or helping persons to stand up. Such tasks are the reason why caregivers often suffer from musculoskeletal disorders, such as back pain. Various robotic systems are already used to relieve the burden on caregivers. Passive exoskeletons have only recently been offered to provide physical relief. Research from other industries and among caregivers shows that objective physical relief can be achieved through the targeted use of passive exoskeletons. To date, however, there is no research on caregivers' subjective perceptions of wearing passive exoskeletons in their daily work.

Population and methods: This case study refers to the perception of four caregivers (m = 1; f = 3) in an inpatient long-term care facility. Two different passive exoskeletons were worn during the shift on different days for on average 5.75 hours. Subsequently, a self-developed questionnaire was completed by the caregivers after having worn both exoskeletons.

Results: All subjects perceived a subjective physical relief by wearing both exoskeletons. The exoskeletons were perceived as comfortable, especially in the lumbar spine region. In general, it can be stated that caregivers are so far hardly aware of the existence, the functionality, and the benefits of passive exoskeletons for care until they get the opportunity to wear and try one.

Discussion and conclusion: Structure and functioning of the exoskeletons seem to make a difference on the perception of the passive exoskeleton. Prior information could increase acceptance by the caregivers.

Hintergrund: Stationäre Pflegekräfte sind bei ihren täglich wiederkehrenden Arbeitsaufgaben von schweren körperlichen Tätigkeiten betroffen. Dazu gehört das Umlagern von Personen oder die Hilfe beim Aufstehen. Solche Aufgaben sind der Grund dafür, dass Pflegende häufig unter Muskel-Skelett-Erkrankungen leiden, wie z. B. Rückenschmerzen. Verschiedene robotische Systeme werden bereits eingesetzt, um Pflegekräfte zu entlasten. Passive Exoskelette werden erst seit kurzem zur körperlichen Entlastung angeboten. Forschung aus anderen Branchen und bei Pflegekräften zeigt, dass durch den gezielten Einsatz von passiven Exoskeletten eine objektive körperliche Entlastung erreicht werden kann. Bisher gibt es jedoch keine Untersuchungen über die subjektive Wahrnehmung des Tragens von passiven Exoskeletten bei der täglichen Arbeit durch die Pflegenden.

Population und Methoden: Diese Fallstudie bezieht sich auf die Wahrnehmung von vier Pflegekräften (m = 1; w = 3) in einer stationären Langzeitpflegeeinrichtung. Zwei

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verschiedene passive Exoskelette wurden während der Schicht an verschiedenen Tagen für durchschnittlich 5,75 Stunden getragen. Anschließend wurde ein selbstentwickelter Fragebogen durch die Pflegekräfte ausgefüllt, nachdem sie beide Exoskelette getragen hatten.

Ergebnisse: Alle Pflegenden empfanden eine subjektive körperliche Entlastung durch das Tragen beider Exoskelette. Die Exoskelette wurden als angenehm empfunden, insbesondere im Bereich der Lendenwirbelsäule. Generell kann festgestellt werden, dass die Existenz, die Funktionalität und die Vorteile von passiven Exoskeletten für die Pflegenden bisher kaum bekannt sind, bis sie die Gelegenheit bekommen, ein Exoskelett zu tragen und auszuprobieren.

Diskussion und Schlussfolgerung: Der Aufbau und die Funktionsweise eines Exoskeletts scheinen einen Unterschied in der Wahrnehmung des passiven Exoskeletts zu machen. Eine vorherige Information könnte die Akzeptanz durch die Pflegenden erhöhen.

KEYWORDS

Passive exoskeletons, nurses, testing, inpatient care, opinion

Passive Exoskelette, Pflegepersonal, Test, stationäre Pflege, Meinung

1. Background

The quest for new innovations is a driving factor in business, amongst others to keep pace with competing companies in the market. In the area of product innovations, a trend towards technical and digital assistance systems (e.g. head-up displays, wearables, cameras) can be identified, which also include various types of robots or so-called exoskeletons.

Exoskeletons are body-mounted mechanical structures (De Looze et al. 2016; Hensel & Keil 2018). Different classifications of exoskeletons exist, depending on the intended use, supported body region, and mechanism of action. The most common delineation distinguishes between active, passive, and semi-active exoskeletons. Active exoskeletons are powered, e.g., electrically, or pneumatically. Passive exoskeletons provide support by transferring power from the human to the exoskeleton and back again to the human, e.g., by springs without drive. Semi-active exoskeletons

can be a combination of both. This means that the exoskeleton primarily works purely mechanically without a drive (passive) but can provide additional support as needed through a drive with supplied electrical or pneumatic energy (active component) (De Looze et al. 2016; Stewart et al. 2017).

Furthermore, exoskeletons can also be distinguished in terms of whether they support the whole body or only parts, such as the trunk or extremities like the arms or legs.

Technical assistance systems, including robots and exoskeletons, are already being used in many sectors, such as manufacturing in industry. There, very high forces and loads often occur for the body of the workers, for example through carrying, lifting, or working overhead. Therefore, robots and active exoskeletons are often used in industrial manufacturing (e.g. the automotive industry), which can provide the person with physical support for the forces that occur (Pacifico et al. 2022). In their investigation of passive exoskeletons, Glitsch et al. (2020) demonstrated that exoskeletons can provide physical relief during activities such as lifting or carrying loads in industry. The more frequently the physically demanding activities are performed, the greater and therefore the more important, in terms of prevention, is the relief for the body. Many models of exoskeletons are aimed at relieving pressure in the areas of the lumbar spine. Little research has been conducted on the physical support on caregivers. However, since the passive exoskeletons for caregivers are sometimes hardly modified and function similarly to models used in industry, it can be assumed that passive exoskeletons can bring physical relief for caregivers as well (Dittrich 2019).

In the healthcare sector, robots and exoskeletons have so far been predominantly used in rehabilitation. Here, the application can relate to different types and severities of diseases and injuries as well as to different body regions (Gülke et al. 2018; Shore, de Eyto & O'Sullivan 2020). One example is assistive robotics for early mobilization of critically ill and intensive care patients. Reactive Robots (2022) indicate that their early mobilization by the robot VEMOTION, based on a patient-initiated movement therapy, minimizes secondary complications, and supports the recovery process. Research shows that self-initiation of the motor movement command is essential for functional improvement. In comparison, rehabilitation therapies were significantly less successful when patients were only passively moved (Donati et al. 2016). They state that without VEMOTION, multiple caregivers would otherwise be needed for an extended period to mobilize the person by hand.

Managers in the care sector consequently also recognized the benefits of exoskeletons for their employees. Therefore, passive exoskeletons for care were developed by some companies. For not too long, passive exoskeletons for caregivers are purchasable on the market. The technical functions of the manufacturers' existing models of passive exoskeletons are usually only slightly adapted. For example, grip options for the person in need of care are added on the exoskeleton. This facilitates the task of lifting the person in need of care by the caregiver (HUNIC GmbH 2022).

Research on the perception of exoskeletons in industry has already been conducted by Elprama, Vanderborght & Jacobs (2022), who identified various acceptance factors of persons when wearing the exoskeletons. These include perceived usability and comfort of wearing the exoskeleton. They conclude that consideration of these factors is important early in industrial development of exoskeletons. In general, research on the acceptance of technology use in care shows that aids for physical support, including lifting aids, are particularly well accepted insofar as they are also available for use (Zöllick 2020).

Whether a new technology proves to be practical in use depends on other factors besides the health benefits. One decisive factor is the perception of the people using the technology, in this case the caregivers testing the passive exoskeletons in inpatient long-term care facilities, in their real-life working environment. So far, no research of caregivers testing passive exoskeletons in inpatient care facilities has been identified.

Aim: The aim of the case study is to present the perception of caregivers in inpatient long-term care on using passive exoskeletons in their real-life working environment.

Population: Four caregivers (n = 4) of an inpatient long-term care facility tested the passive exoskeletons. The demographic data of the nursing staff are shown in Table 1:

Participant	1	2	3	4	Mean
Age (years)	34	59	53	20	41.5
Gender (m/f/d)	m	f	f	f	m = 1; f = 3
Physical complaints	yes	yes	yes	NA	yes = 3; NA = 1

Table 1: Demographic data

Participants received use and safety instructions before wearing the two exoskeletons.

2. Methods

A self-developed questionnaire was set up and completed by the nurses after wearing the exoskeletons during work. It contained quantitative and qualitative questions. The questionnaire was divided into the following four sections: 1) CareExoLift, 2) Rakunie, 3) general questions about wearing both exoskeletons, 4) sociodemographic data. The complete questionnaire is shown in Appendix 1. Two models of passive exoskeletons were worn, the CareExoLift from Hunic GmbH (2022) and the Rakunie Back Support from awb Schraubtechnik- und Industriebedarf GmbH (2020).

The two models differ in terms of provided information from the manufacturers. The CareExoLift is a one-size-fits-all model, weighs 3.52 lbs (pounds) and covers the entire body from shoulders to ankles. It relieves pressure by up to 21 percent depending on the degree of adjustment. The Rakunie Back Support is no one-size-fits-all model and can be purchased in a variety of sizes. It weighs about 0.55 lbs and goes from the shoulders to the knees. According to the manufacturer, it relieves the spine by 20 percent during activities in forced bending postures. It can also be worn underneath clothing.

Three persons wore the exoskeleton on one day, one person on two days. The average total wearing time of the exoskeletons per person was 345 minutes (= 5.75 hours) each.

Figure 1: Rakunie Back Support (awb Schraubtechnik- und Industriebedarf GmbH, 2020)

Figure 2: CareExoLift (HUNIC GmbH, 2022)

3. Results

The exoskeletons were mainly worn for nursing care activities, among which the lifting and repositioning of persons from beds or chairs as well as personal hygiene activities were mentioned. When asked for which activities the exoskeletons helped the most, heavy lifting and bending activities were mostly mentioned.

All subjects felt a subjective physical relief by wearing both exoskeletons. The exoskeletons were perceived as comfortable on the back, especially in the lumbar spine region (n = 7 for both models). The CareExoLift was found to be irritating at the shoulders (n = 1), knees (n = 1) and legs (n = 1), the Rakunie Back Support nowhere. In none of the models did a dangerous situation occur caused by wearing the exoskeletons. In most cases, the exoskeletons did not negatively restrict the movements of the caregivers (n = 7 for both models).

The following adjectives were mentioned by the caregivers as descriptions for the CareExoLift: helpful, pleasant, relieving, supporting, back-saving, disturbing, irritating, different. For the Rakunie Back Support, the adjectives pleasant, helpful, good, easy, relieving, gentle on the back, not irritating were named.

The caregivers mentioned several suggestions for improving the design of the CareExoLift. One is a request for more legroom. Also, a one-size-fits-all model is not very suitable for people who are very small or tall. Another suggestion is to place the side straps differently to allow for a coat pocket handle, and to omit the side handles for care recipients, as these can cause demented individuals to fall if they do not let go of the handles.

If the employer would purchase one of these two exoskeletons, caregivers would wear both models regularly during daily work (n = 8 for both models).

The following table presents additional quantitatively collected results.

Question	Model	Answers Participant				Mean
		1	2	3	4	
How practical did you find the donning and doffing of the exoskeleton?	CareExoLift	3	3	2	4	3
	Rakunie Back Support	1	2	1	2	1.5
How have care recipients responded to the exoskeleton?	CareExoLift	3	3	1	1	2
	Rakunie Back Support	3	3	1	1	2
How were your attitudes toward the exoskeleton prior to first use?	CareExoLift	1	2	1	1	1.25
	Rakunie Back Support	1	2	1	1	1.25
In general, how would you rate the benefits of using the exoskeleton in your everyday work?	CareExoLift	1	2	2	2	1.75
	Rakunie Back Support	3	3	1	1	2
How does wearing the exoskeleton on the body feel in general?	CareExoLift	2	3	2	3	2.5
	Rakunie Back Support	1	2	1	2	1.5

Table 2: Results of questions concerning the use of both passive exoskeleton models. *Please tick the most applicable answer for each question: 1 (good/positive), 2 (rather good/positive), 3 (medium), 4 (rather poor/negative), 5 (poor/negative)

The results show that there are differences between both models in terms of different dimensions. The attitudes toward the exoskeleton prior to first use were positive (m = 1.25 for both models). Furthermore, the care recipients responded rather positive to the exoskeleton (m = 2 for both models). Whereas the CareExoLift was more complicated in donning and doffing (m=3) compared to the Rakunie Back Support (m=1.5), there was hardly any difference in the rated benefits when wearing in everyday work. The participants rated the models differently with respect to how it felt to wear them on the body (CareExoLift m = 2.5; Rakunie Back Support m = 1.5).

In addition, general questions were asked about the knowledge of passive exoskeletons prior to the initial contact with the exoskeletons. Only one person knew before testing that passive exoskeletons for caregivers are already produced and offered. Also, only one other person knew before testing how a worn, passive exoskeleton works and that such a passive exoskeleton can provide physical relief in everyday work.

4. Discussion and conclusion

One limitation of this study is the small case number. Therefore, it is referred to as a case study. Thus, the external validity is limited, but allows first indications on the perception of caregivers on the use of passive exoskeletons during daily work.

In addition, most participants (n = 3; 75 %) reported physical complaints. The quest on physical complaints in the questionnaire was not defined more precisely but kept open. Logically, technical assistance systems are perceived as more helpful for people with physical complaints since the perceived benefit is higher. Therefore, it cannot be excluded that passive exoskeletons are considered less helpful by people without physical complaints (Kozinc, Babič & Šarabon 2021). Such a population could be constituted by younger people. A survey by von der Lippe et al. (2021) shows that in Germany, older people are more frequently affected by neck and back pain attacks than younger people.

The last question in Table 2 shows that both models felt rather good to wear on the body in general, but there was a difference between the models. It indicates that construction makes a difference on the acceptance and exoskeletons need to be adjusted to the work of caregivers to be better accepted.

Caregivers seem to have little knowledge about the existence, functionality, and benefits of passive exoskeletons in caregiving. It is possible that providing information could reduce reservations towards technical assistance systems. The investigated population seems to have a positive attitude about testing passive exoskeletons and feel a positive effect on their physical exertion when wearing them. The case study supports previous research showing that wearing comfort and ease of use, such as donning and doffing, should be a given (Schwerha et al. 2022). Furthermore, the case study indicates that the structure and functioning of the exoskeletons seems to make a difference on perception by the caregivers (Elprama et al. 2022).

In this pilot study, the acceptance factors perceived safe use of exoskeletons, perceived usefulness of exoskeletons, general attitude towards exoskeletons, existing knowledge about exoskeletons (psycho-socio factors), personal history of physical complaints, wearing comfort of exoskeletons (physiological factors) and ease of using an exoskeleton (implementation-related factors) were addressed. These acceptance factors in caregivers are consistent with findings of Elprama et al. (2022). In their framework of exoskeletons acceptance in industry, they showed that the factors identified in this pilot study and other factors are critical for exoskeleton acceptance. The factors can be classified in the dimensions psycho-socio, physiological, implementation-related, work-related, and policy-related.

Further in-depth qualitative research is needed to identify the comprehensive range of acceptance factors of exoskeletons among caregivers.

Conflict of interest statement

The author declares that no conflict of interest exists with respect to the publication of this work.

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Appendix 1:
Eingesetzter Fragebogen

1) HUNIC GmbH

An wie vielen Tagen haben Sie das Exoskelett getragen? ___

Wie viele Minuten haben Sie das Exoskelett ca. pro Tag getragen? ___

Empfanden Sie eine körperliche Entlastung beim Tragen des Exoskelettes? Ja □ nein □

Empfanden Sie das Exoskelett an einer bestimmten Stelle des Körpers als angenehm? Ja □ nein □
Wenn ja, an welcher/n Stellen? ___

Empfanden Sie das Exoskelett an einer bestimmten Stelle des Körpers als störend? Ja □ nein □
Wenn ja, an welcher/n Stellen? ___

Kam es durch das Tragen des Exoskelettes während der Schicht zu einer gefährlichen Situation?
Ja □ nein □
Wenn ja, wie bzw. warum? ___

Hat Sie das Exoskelett in Ihren Bewegungsabläufen negativ beeinträchtigt? Ja □ nein □
Wenn ja, inwiefern? ___

Wie fühlte sich das Tragen des Exoskelettes an? (Bitte nennen Sie nur Adjektive; z.B. angenehm, hilfreich, störend, irritierend) [Adjektiv 1]

Wie fühlte sich das Tragen des Exoskelettes an? (Bitte nennen Sie nur Adjektive; z.B. angenehm, hilfreich, störend, irritierend) [Adjektiv 2]

Wie fühlte sich das Tragen des Exoskelettes an? (Bitte nennen Sie nur Adjektive; z.B. angenehm, hilfreich, störend, irritierend) [Adjektiv 3]

Wie fühlte sich das Tragen des Exoskelettes an? (Bitte nennen Sie nur Adjektive; z.B. angenehm, hilfreich, störend, irritierend) [Adjektiv 4]

Wie fühlte sich das Tragen des Exoskelettes an? (Bitte nennen Sie nur Adjektive; z.B. angenehm, hilfreich, störend, irritierend) [Adjektiv 5]

Welche Verbesserungsvorschläge haben Sie für die Konstruktion des Exoskelettes? ___

Im Falle eines Erwerbes eines Exoskelettes durch Ihren Arbeitgeber, würden Sie das Exoskelett regelmäßig nutzen wollen? Ja □ nein □

Bitte kreuzen Sie für jede Frage die zutreffendste Antwort an:
1 (gut/positiv), 2 (eher gut/positiv), 3 (mittel), 4 (eher schlecht/negativ), 5 (schlecht/negativ):

- Wie praktikabel empfanden Sie das An- und Ausziehen des Exoskelettes?
- Wie haben die Pflegebedürftigen auf das Exoskelett reagiert?
- Wie waren Sie vor der ersten Nutzung gegenüber dem Exoskelett eingestellt?
- Wie würden Sie allgemein den Nutzen des Einsatzes des Exoskelettes in Ihrem Arbeitsalltag bewerten?
- Wie fühlt sich das Tragen des Exoskelettes am Körper im Allgemeinen an?

Wie praktikabel empfanden Sie das An- und Ausziehen des Exoskelettes? Schildern Sie bitte kurz Ihren Eindruck. ___

2) Rakunie

(selbe Fragen wie für HUNIC GmbH)

3) Allgemeine Fragen zum Tragen beider Exoskelette

Bei welchen Tätigkeiten haben Sie das Exoskelett getragen? ___

Bei welchen Tätigkeiten während der Arbeit half Ihnen das Exoskelett am meisten? ___

Sehen Sie eine Gefahr für sich oder die pflegebedürftige Person durch das Tragen des Exoskelettes?
Ja □ nein □
Wenn ja, welche Gefahr/en?

Wussten Sie bereits zuvor, dass Exoskelette für Pflegende entwickelt werden? Ja □ nein □

Wissen Sie in etwa, wie ein von Ihnen getragenes, passives Exoskelett funktioniert? Ja □ nein □

Wussten Sie bereits zuvor, dass Sie ein passives Exoskelett körperlich entlasten kann? Ja □ nein □

Haben Sie körperliche Einschränkungen oder Beschwerden? Ja □ nein □

4) Soziodemografische Daten

Alter? ___Jahre

Geschlecht? männlich □ weiblich □ divers □

Lukas Schmidbauer

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Proposing a Framework for Virtual Teaching at the European Campus Rottal-Inn (ECRI)

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ABSTRACT

***Background*: Digital education aims at minimizing interferences to education among challenging times such as during COVID-19, and empowering students to experience new tools and resources while at the same time creating a safe place for educators to have control over the teaching process. *Aims*: With this study, the project CREATE aimed at examining the experiences of academic students with their first weeks of online teaching post COVID-19. The specific aim was to map their experiences and acquire knowledge in order to make necessary short-term adjustments in the subsequent rounds of online teaching through proposing the structure for online teaching framework. *Method*: This framework is based on identifying students' perspectives with a distributed survey towards virtual teaching in the timeframe of pre- and post COVID-19 restrictions situations. *Results*: The results provide a framework for accessing methods and content in the form of delivery formats needed to be included in the curriculum for specialty development of online teaching. *Conclusion*: The methodology and results presented in this study may prove useful to educational institutions determined to target professional development curricula for students, with the criteria and skills needed to successfully organize online teaching.**

Hintergrund*: Die digitale Bildung zielt darauf ab, die Beeinträchtigung des Unterrichts in den schwierigen Zeiten wie während der COVID-19-Pandemie zu minimieren und den Studierenden die Möglichkeit zu geben, neue Werkzeuge und Ressourcen kennenzulernen, während gleichzeitig ein sicherer Ort für die Lehrenden geschaffen wird, um die Kontrolle über den Lehrprozess zu behalten.* **Ziele***: Mit dieser Studie zielte das Projekt CREATE darauf ab, die Erfahrungen von Hochschulstudierenden mit ihren ersten Wochen des Online-Unterrichts nach COVID-19 zu untersuchen. Das spezifische Ziel bestand darin, ihre Erfahrungen zu erfassen und Erkenntnisse zu gewinnen, um in den folgenden Runden des Online-Unterrichts die notwendigen kurzfristigen Anpassungen vorzunehmen, indem eine Struktur für den Online-Unterrichtsrahmen vorgeschlagen wurde.* **Methode***: Dieser Rahmen basiert auf der Identifizierung der Perspektiven der Studierenden mit einer verteilten Umfrage zum virtuellen Unterricht in der Zeit vor und nach den COVID-19-Beschränkungen.* **Ergebnisse***: Die Ergebnisse bieten einen Rahmen für den Zugang zu Methoden und Inhalten in Form von Lehrformaten, die in den Lehrplan für die Entwicklung von Online-Lehrveranstaltungen aufgenommen werden müssen.* **Schlussfolgerung***: Die in dieser Studie vorgestellte Methodik und die Ergebnisse können sich für Bildungseinrichtungen als nützlich erweisen, um Lehrpläne für die berufliche Entwicklung von Studierenden mit den Kriterien und Skills zu erstellen, die für die erfolgreiche Organisation von Online-Unterricht erforderlich sind.*

KEYWORDS

COVID-19, framework, format, online teaching, online learning

COVID-19, Rahmen, Format, Online-Unterricht, Online-Lernen

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1. Introduction

The physical closure of universities and university colleges in Germany and COVID-19 disruptions have also resulted in the transformation from real-time lecturing to digital education or electronic learning (e-learning) [1]. However, this does not imply that the applicable digital technologies and related skills are being effectively in use. Across Germany, academics, administrators, and information technology (IT) supported a series of bottom-up initiatives by the National and European policies which acknowledge the need to provide a structure which allows the use of digital technologies creatively [2].

In addition to the fundamental IT application in teaching, the recognizable proof of criteria and the demand for proposing a framework for online teaching are indispensable requirements in education [3]. Many research results show that the integration of technology has many benefits for both teachers and students in the teaching process [4, 5]. For instance, from the Deggendorf Distance Learning Model (DEG-DLM) research project, which was undertaken at the Deggendorf Institute of Technology, it can be deduced that the use of technology-supported teaching was generally well received by the students. Considering the fact that the learners were granted a high degree of flexibility in terms of location and time through the use of digital teaching formats, it can be assumed that blended learning approaches can play an important role in the future of in-service adult education [6]. However, a sense of enhancing the online teaching is central to students' satisfaction [7, 8]. Drawing on students' engagement is essential for developing strategies for online teaching. Setting the strategies for developing the online teaching framework is based on testing and exploring students' perceptions towards online teaching [9].

This study aims at proposing the structure for an online teaching framework. This framework is based on identifying students' perspectives towards virtual teaching in the timeframe of pre- and post-COVID-19 restrictions situations. The specific aim was to map their experiences and acquire knowledge in order to make necessary short-term adjustments in the subsequent rounds of online teaching. Thus, it would help in proposing a storyboard of e-learning tools and instructional learning video type according to the type of teaching course. The framework also proposes a progression model to help educators assess and develop their digital competence.

2. Related Work

2.1 European framework in online teaching

In proposing the online teaching framework, various tools and recommendations are involved in different phases. Figure 1 illustrates six major areas to be involved in concerning the online teaching framework: professional engagement and organizational communication, selecting digital resources, planning the teaching process according to digital devices and resources, assessment strategies and results efficiency, empowering learners with content accessibility and finally facilitating learners' digital competence. Thus, it should cover examining the context of the course content and determining the learning programme suitability. Additionally, it also aims to include designing instructional strategies, activities and assessments that will reach the teaching objectives while at the same time helping learners to improve their e-learning performance. This is achieved through choosing the most appropriate learning modality and delivery format accordingly to the course context. E-learners' performance is also enhanced through constant supervision and establishing mechanisms to assess the efficiency and effectiveness of the teaching method (see Figure 1) [10].

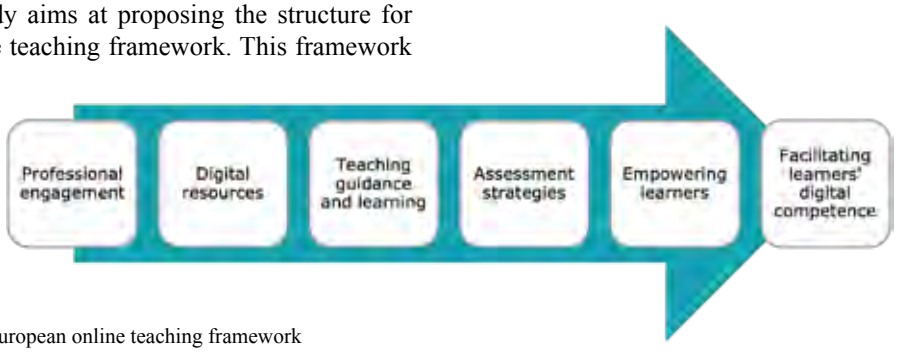

Figure 1: European online teaching framework

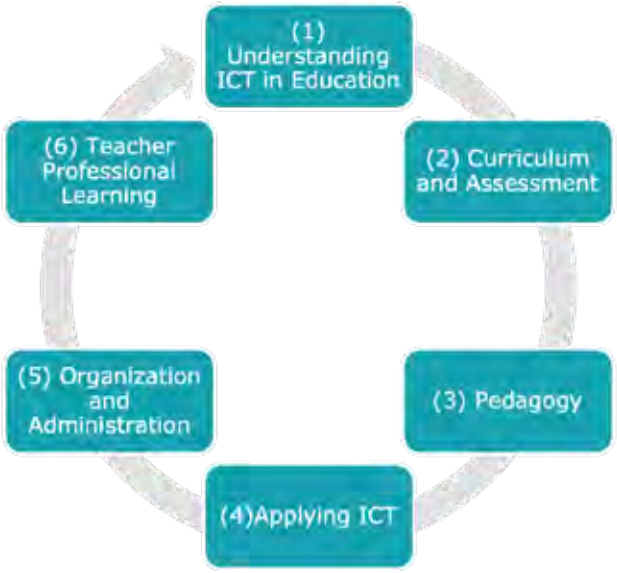

Figure 2: UNESCO online teaching framework

2.2 World-wide framework in online teaching

According to UNESCO: In 2011, the United Nations Educational, Scientific and Cultural Organization (UNESCO) established an ICT (Information Communication Technology) Competence Framework for Teachers, where the competence framework covers six dimensions (see Figure 2). This includes: (1) Understanding ICT in Education, (2) Curriculum and Assessment, (3) Pedagogy, (4) Applying ICT, (5) Organization and Administration, (6) Teacher Professional Learning. Each aspect consists of three levels of endurance in the advancement of teacher competences: technology literacy, knowledge deepening, knowledge creation [11].

3. Methodology

This study used a qualitative method. Based on a students' survey and a previously published study, principles were identified. In this study section, we used investigation results for data collection analysis methods. Thus, the efficiency of e-learning instructional approaches including Distribution, Analysis, Design, and Development was optimized.

3.1 Distribution

Non-probability sampling with a convenience sampling technique was used to recruit participants who are convenient to participate by an invitation to an online survey link.

3.2 Analysis

Target audience analysis is a major step in proposing a framework for virtual teaching. The design and delivery of electronic instructional approaches will be influenced by key characteristics of the e-learning learners, i.e. their previous knowledge and skills, geographical provenience, learning perspectives and context, and access to technology, while all the direct and indirect identifiers were excluded from the sampling.

3.3 Design

The design stage encompasses i) formulating a set of questionnaires to achieve the general, high-level project objectives, ii) testing capabilities of e-learners towards technology's use, and iii) selecting instructional, media, evaluation, and delivery strategies.

This stage involves testing students' perceptions towards applied teaching tools during COVID-19 restrictions using a questionnaire. This questionnaire is part of a study on the capabilities of technology to provide effective virtual teaching and learning experience. The purpose of this survey is to assess academic lecturers and learners' perceptions towards digital teaching, including concrete needs and existing challenges, and to provide an outcome of preferred teaching formats and processes.

This survey was created using Google Forms. The questions contain different question formats including Likert scale, matrix, dropdown, open-ended, and single or multiple-choice questions. The questionnaire is divided into three sections: academic disciplines and teaching hours, perception towards online teaching during COVID-19, and instructional approaches. To ensure its effectiveness, all the answers are strictly confidential, and no personal identification is done.

3.4 Development

In this stage, the e-learning modified tools for the e-learning content are suggested. The selection of the tools can vary considerably, depending on the available content and selected instructional approaches. The development of e-learning tools encompasses storyboard development, which is a document that describes all the components of related interactive teaching tools.

3.4 Evaluation

The e-learning project is endured an evaluation for specific purposes. This involves addressing electronic learners' reactions, the achievement of learning objectives, the transfer of professor's related knowledge and skills, as well as the impact of the project on Deggendorf Institute of Technology, European Campus Rottal-Inn.

4. Results

4.1 Situation of online teaching pre-COVID-19

Based on the published study "Increasing Efficiency in Virtual Teaching in an International Context: E-learning and Instructional Approaches at ECRI" [12], various teaching formats such as lecture and whiteboard, seminars, laboratory work, field trips, case study, and online teaching were identified according to subject classification levels in science (see Figure 3). Results had also shown that in comparison to the other courses, (B.A.) International Tourism Management had the highest number of classroom-independent teaching events. Digital education aims at minimizing interferences to education among challenging times such as during the COVID-19 pandemic, and empowering students to experience new tools and resources while at the same time creating a safe place for educators to have control over the teaching process.

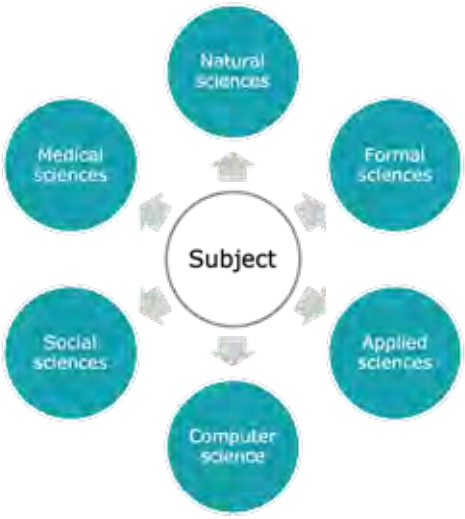

Figure 3: Subject classification levels in science

4.2 Situation of online teaching post-COVID-19

Prior to the proposal of the framework, it is necessary to identify the main components in facilitating digital competences in learning. Figure 4 shows an overview of the key concepts used in this study.

4.2.1 Proposing the structure of the online teaching framework for lecturers

In order to build the framework in line with the online teaching, and to approach the international trend, we will base the online teaching framework (see Figure 5) on the

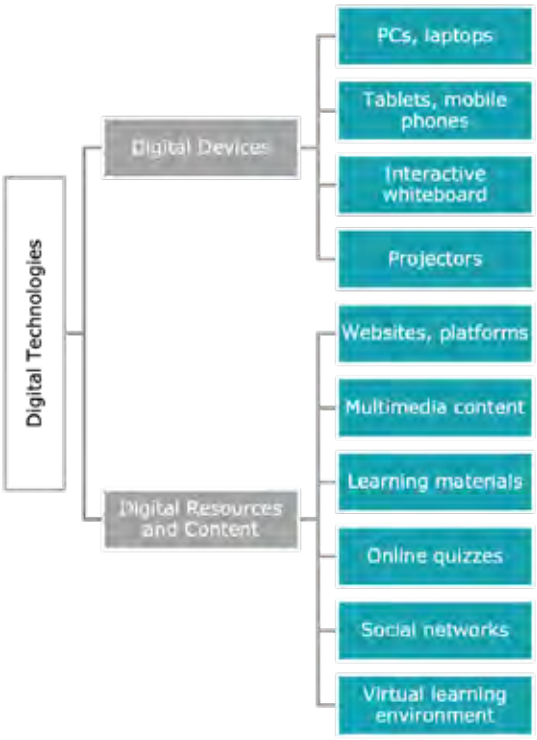

Figure 4: An overview of the key concepts in this study

following principles:

1) Students' perceptions
2) Instructional learning video type
3) Expositive-based teaching subjects
4) Application-based teaching subjects
5) Delivery format

Table 1 shows six suggested instructional learning videos, which encompasses flipped or inverted classroom videos, auditory visual learning, interactive videos, animations, video recordings, and slide cast. The first instructional approach involves expositive teaching methods, which encompasses presentations,

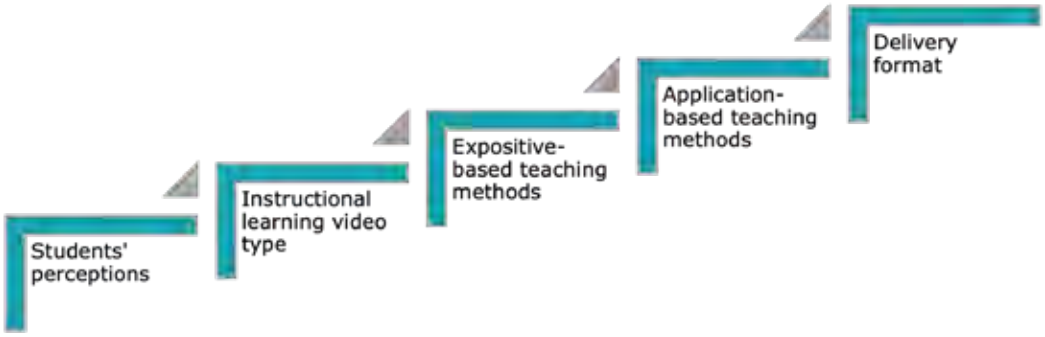

Figure 5: Proposed structure of online teaching framework principles

case studies, and worked examples. Table 2 presents the delivery formats under expositive methods. The second instructional approach involves application teaching methods, which encompasses demonstration of practicing methods to develop procedural skills such as laboratory work. These methods allow the learners to practice through applying the gained knowledge. Table 3 presents the delivery formats under application methods.

A survey on 102 students studying bachelor courses (B.Sc.) Health Informatics; (B.Eng.) Energy System Engineering and (B.A) International Tourism Management was carried out at the Faculty European Campus Rottal-

Inn (ECRI) of the Deggendorf Institute of Technology (DIT).

In this survey, students have proposed various opinions towards learning remotely. The purpose was to assess students' perceptions towards digital teaching including concrete needs and existing challenges and to provide an outcome of preferred teaching formats and processes.

Students' opinions have identified the potential for success in online teaching. Through the results of our investigations and analysis of the success in online teaching, we propose basic criteria for an online teaching framework based on these opinions (see Figure 6).

To achieve a user-friendly learner experience, and enhance students performance in various

Instructional learning video types
Flipped or inverted classroom videos (maximum 15 minutes recorded lecture)
Instructional videos supported by auditory-visual learning
Interactive videos
Animations
Video recordings of courses
Slide cast (parallel recording of the audio track of the oral lecture)

Table 1: Instructional learning video types

Delivery Format
Documents and PPT slides
Interactive e-learning lesson (interactive E-book)
Online educational videos
Webcasting (video lessons and podcasts)
Webinars (video/audio conferencing, chat-based)
Virtual classroom

Table 2: Expositive teaching methods and related delivery formats

Delivery Format
Combination of application sharing, animations, and real practice
Glossaries, templates
Electronic branched scenarios
Interactive whiteboard
Individual tutored activity in person
Online group activity

Table 3: Application teaching methods and related delivery formats

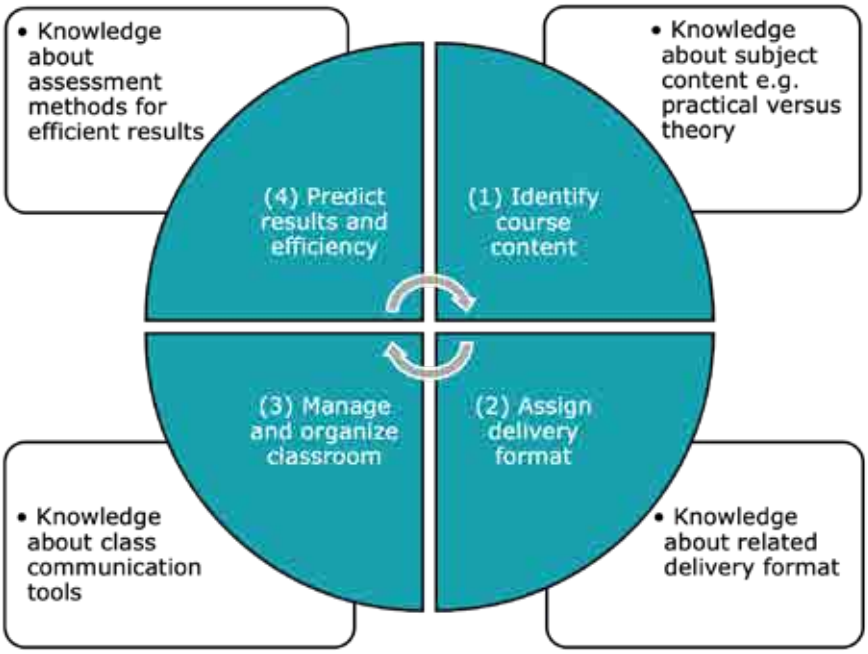

Figure 6: Basic criteria for an online teaching framework based on students' extracted free text

aspects of learner-computer interaction including: information, content, accessibility, relevance, and ease of use. Thus, further description and related suggested improvements are recommended accordingly to previously proposed criteria for online teaching framework (see Figure 7). Improvements in key concepts for approaching online accessibility involved perceivable, operable, understandable and robust.

To achieve a user-friendly learner experience,

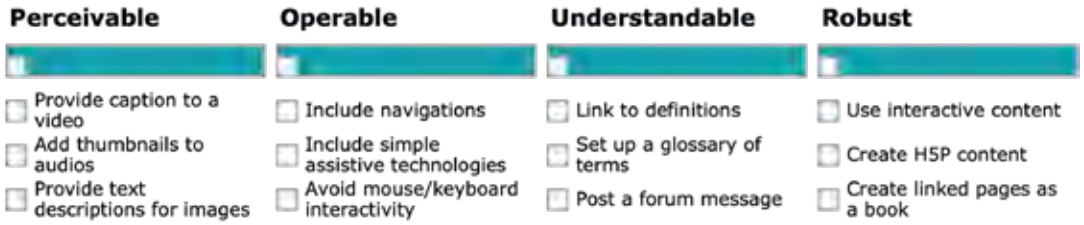

Figure 7: Online teaching improvements in key concepts and related recommendations

and enhance students performance in various aspects of learner-computer interaction including: information, content, accessibility, relevance, and ease of use. Thus, further description and related suggested improvements are recommended accordingly to previously proposed criteria for online teaching framework (see Figure 7). Improvements in key concepts for approaching online accessibility involved perceivable, operable, understandable and robust. In proposing the online teaching framework at the European Campus Rottal-Inn, various tools and recommendations are involved in different phases. The paper shows a list of activities that are examples of digital competence that serves to indicate to framework users what kinds of criteria are covered by the competence in question. How to determine the criteria, measure their value, and evaluate their effectiveness when applying the framework to online teaching needs to be clarified. The building of a framework must cover general capacity, professional competence, and management capacity to solve the elements of mission objectives, standards, and capacity requirements in online training and promote

efficiency in teaching methods towards developing the competence of students.

5. Conclusion

With this study, the project CREATE aimed at examining the experiences of academic students with their first weeks of online teaching post-COVID-19. The specific aim was to map their experiences and acquire knowledge in order to make necessary short-term adjustments in the subsequent rounds of online teaching. As the dataset is relatively small, due to the limited response, generalizations and exhaustive conclusions based on these findings are not within the scope of this report. Nonetheless, the study offers a first insight into the students' experiences with a drastic change in the delivery of their e-learning, and provides basic data that can be compared with future evaluations. These study results provide a framework for accessing methods and content in the form of delivery formats which needed to be included in the curriculum for specialty development of online teaching. The methodology and results presented in this study may prove useful to educational institutions determined to target professional development curricula for students, with the criteria and skills needed to successfully organize online teaching.

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Conflicts of interest statement

The authors declare that there is no conflict of interest regarding the publication of this paper.

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