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A Standardised Digital Maturity Index and the Application to Higher Education

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Abstract

Digital change is everywhere. Higher Education Institutions (HEIs) are adopting advanced digital tools and pursuing digital strategies. In order to monitor the success of these efforts, the ongoing changes need to be made visible, i.e., objectively quantified. Consequently, there is a need for comparative measures to provide specific guidance and the potential for a neutral overview. Often, institutions compare their development either at the level of management by objectives or in benchmarking initiatives specific to the type of university. Measures are required to continuously deliver data even in the midst of major organisational changes. Currently-used measures often are subjective to the observer and the institution. If so, they are less suitable for the purposes mentioned above. This paper presents a Digital Maturity Index (DMI), which is generic in its structure but can be easily adapted to a specific sector such as the higher education ecosystem. It consists of 11 simple fact-based, closed-ended questions about the evaluated organisational scope, such as a process or a business capability. The index items have been validated and the relative weights have been adjusted from a broad national survey of one-third of all German universities, hence the derived weights reflect common expectations of this sector.

In addition to validating the index, the results are applied to the rest of the survey data. The status of digitisation in German higher education is presented using the Higher Education Reference Model (HERM). Additional insights made possible by the robust but discriminating measurement of the new tool are presented. A summary discusses the index's potential, shortcomings, and additional areas of application.

Keywords: Maturity, Digital Index, Enterprise Architecture, National Survey, Higher Education, Germany

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1 Introduction

Further advancements in cultural, technological, and organisational change are necessary when organisations face the challenges of digital transformation (Dx). Higher education institutions (HEI) like universities, technical universities, or universities of applied sciences release strategic papers to guide the digital development of their complex organisational structures. Many changes are driven by external demands (legislative regulations, politics, the general public) or internal expectations (of students, teachers, researchers or administrative staff). While developments seem to be accelerating, leaders are trying to keep track and measure their progress in digital transformation.

Depending on the scope of digital maturity, approaches can focus on either a) the technical level of how tools are implemented and how operations are managed, or b) the change brought about by digital transformation. Successful application of a model in one sector often is based on adaptations to reflect specific requirements. Digital maturity models have previously been proposed in higher education for both approaches.

A technologically-oriented model was proposed by (Gilch et al., 2019). A four-stage model covered the aspects of user experience along the spectrum of paper-based processes, the additional help provided online, the use of online forms and the complete digital process without media discontinuities.

EDUCAUSE presented a self-assessment tool[2] to lay the groundwork for a transformational perspective in higher education. Typically, a digital maturity score would include measures of strategy, leadership and governance, infrastructure, talent, culture, customer experience, marketing, operations, innovation, data and analytics, risk and security, and partnerships and ecosystems. As shown in (von der Heyde, 2022c), the EDUCAUSE self-assessment can be applied to the German higher education sector to measure a digital transformation score (Dx-Score) based on the complex combination of more than 20 items statistically linked to an overall judgement of a "perfect digital institution" with reference to (McCormack, 2021).

A more complex approach, both in terms of the methodology for selecting appropriate items and the amount of work involved in the assessment, was presented by (Castro Benavides, 2022). Here, a group of experts agreed on the wording of the items and the coherence of their judgement as to whether a particular item was essential for maturity was derived from the qualitative discussion. The items presented by (Castro Benavides, 2022) covered very similar aspects to the EDUCAUSE approach.

The previous approaches have several shortcomings:

- Assessing the state of digital transformation requires a considerable amount of effort.
- The scores derived could not indicate which step to take next to improve the situation.
- The different items did not have corresponding relative weights or a natural order in which they would typically be addressed by institutions.
- The assessment was oversimplified when reduced to only a few discrete levels as in the Capability Maturity Model Integration (CMMI), making it difficult to derive consequences and actions from the results.
- There is no current overview that allows us to compare the digital maturity of business capabilities across one or more institutions.

To establish an overview across a complete HEI, a generic architecture as the Higher Education Reference Model (HERM) and its Business Capability Model (BCM) published by the CAUDIT Enterprise Architecture Community of Practice (2021) can be used. The model is widely accepted and further developed by CAUDIT, EduCause, UCISA, and the EUNIS Enterprise Architecture Group as described in (Nauwerck et al., 2022).

[2] See further details on the Dx journey and the questionnaire.

This paper aims to mitigate the shortcomings of previous approaches while providing an overview through the application of HERM's BCM. A generic Digital Maturity Index (DMI) is proposed that does not capture process maturity or individual KPIs, but rather groups the digital advances required to achieve specific maturity levels. Section 2 elaborates on the details, showing how to bridge the gap between what had previously been done and what has been successfully implemented by the new DMI. Section 3 applies the maturity rating to HERM's BCM. Finally, the overall contribution is summarised in section 4 to show how the results are valuable for both the internal use by a single institution to monitor development, and the benchmarking between several institutions in a detailed comparison and alignment of their joint efforts or in highlighting their differences as competitors.

2 Standardising digital maturity

This section describes the rationale behind the development of the new Digital Maturity Index. It is based on a short list of requirements. A careful selection of the required items within the scope of the index was made. The index was then fitted to empirical data from a large national survey of the target sector (higher education) in order to include experts' assessments. Finally, the derived index was validated. The index was compared with data collected within the same dataset but not used to determine the index weights.

2.1 Requirements

For the design of the digital maturity index, the following requirements were collected and systematised:

- General features
  - Simple: Clear and concise coverage of the relevant scope.
  - Generic: Measurable items while maintaining a level of abstraction.
  - Flexible: Adaptable to specific sectors through the choice of parameters.
  - Robustness: Missing items or values should not result in major changes.
- Requirements as digital index
  - Relevant: Mixture of Dx-related items.
  - Objective: Derived from facts rather than judgements.
  - Unspecific: Independent of specific technologies
- Requirements to an index suitable for measuring maturity
  - How, not what: Measure how things are done
  - Applicable: To any process or capability in institutions.

The general idea for an index that meets most of these requirements would be a weighted sum of several items. If also divided by the number of items that should be maximally selected, the index would maintain comparability between different approaches on this parameter. A simple approach would be:

DMI = (sum{n=1;n≤MaxSelection} of biggest n item weights at point in time) / MaxSelection

2.2 Selection of items

To simplify the assessment and also clarify the scope, the following new approach was taken. As many of the dimensions (such as talent and culture) have many aspects beyond digital relevance, we limited the matrices to more technology-oriented qualities. There are several generic technological qualities that exist in many different implementations of business processes, such as:

- Reliability: The ability to ensure the reliability and availability of systems and applications and minimise downtime and disruptions.
- Usability: The ability to design systems and applications that are user-friendly and intuitive, and meet user needs and expectations.
- Flexibility: The ability to adapt systems and applications to changing business requirements and processes.
- Standardisation: The extent to which digital processes are standardised and documented to ensure consistency in execution.
- Security: The ability to ensure the security and privacy of data and systems, and protect against cybersecurity threats.
- Scalability: The ability to scale systems and applications up or down to meet changing business needs and demands.
- Integration: The ability to integrate different systems, applications, and data sources to streamline operations and improve data management.
- Continuous Improvement: The level of commitment to continually improving digital processes to optimise performance and meet changing business needs.
- Performance: The ability to optimise system and application performance to ensure they meet performance requirements and deliver a seamless user experience.
- Automation: The ability to automate tasks and processes to increase efficiency and productivity.

As these qualities are abstract and generally difficult to assess, simple indicators were chosen to cover the main aspects. Rather than open-ended questions that would lead to a scaled rating, closed-ended questions were chosen to provide a definitive answer on the current status and future plans. In addition, existing approaches[3] have been incorporated into simple items to enable longitudinal evaluations in the future.

Table 1: Full and partial mapping of the generic digital qualities to specific items used in the dataset by (von der Heyde, 2022d).

Item	Reliability	Usability	Flexibility	Standardisation	Security	Scalability	Integration	Continuous Improvement	Performance	Automation
Paper	full									
Help		full								
Exceptions			full							
Online forms			partial	full						
Roles and rights					full					
No media discontinuity						full				partial
Persistent data							full		partial	
Data quality	partial							full		
Interfaces				partial			full			
Parallel processing						partial			full	
Sampling								partial		full

[3] See collected data by (Gilch et al., 2019) and further evaluations (Gilch et al., 2021; PricewaterhouseCoopers, 2021). We included their maturity rating items as indicated with*.

The 11 items chosen by the dataset were:

- Paper*: The use of printed paper as a data carrier is necessary for the processes.
- Help*: Professional information and help are available online and can be found through search engines.
- Exceptions: It is always possible to intervene in the process to take circumstances into account.
- Online forms*: Can be digitally processed by users after downloading (e.g., using embedded full text, XML and signatures).
- Roles and rights: Responsibilities are mapped digitally.
- No media discontinuity*: The process is entirely electronic.
- Persistent data: Existing data (e.g., from forms and databases) can be reused by users.
- Data quality: Data is enhanced and checked for plausibility as it is entered and processed.
- Interfaces: Data is linked to other processes via standardised interfaces.
- Parallel processing: In some cases, the processing of a case is carried out by several people in parallel.
- Sampling: Processing is largely automated, with manual random checks only carried out on a case-by-case basis.

A mapping of the simplified items to the generic digital qualities is shown in table 1. Essential for this mapping to work is not if the items may also fit partially to several generic qualities, but if all qualities are somewhat covered by at least one item.

In the spring of 2022, a national survey was conducted in Germany to collect CxOs' judgments on the digital transformation of various capabilities (von der Heyde, 2022e). The items introduced in this section were used in the survey to assess the maturity of the HERM capabilities. Participants selected capabilities that were either already significantly transformed by the use of digital tools, or were expected to be changed in the next five years. The ratings of all items differentiated between the current status (now), the intended development during the next five years (5y), a long-term perspective (long term), and if the item was not a goal (no goal).

2.3 Adaptation

To adapt a maturity index to the context of higher education, specific weights need to be assigned to the items. In a mathematical optimization using a Monte Carlo simulation, a set of weights was derived from the data of the same national survey (von der Heyde, 2022d).

First, the data were examined for systematic violations of the chosen error functions. The survey collected three time-based ratings, which allows two comparisons (now vs. 5y and 5y vs. long term). However, the "no goal" aspect would be lost. In addition, detailed analysis showed that only a very small proportion of participants gave multiple answers to the same item. In particular, for the 'paper' item (see above), respondents tended to indicate that they would like to stop using it but did not indicate the current status. The opposite principle (e.g., a fully digital workflow) clearly showed that most institutions still rely on paper within the process. Therefore, the "no goal" option was used as an indicator to also assume the factor "paper" was still at its current status.

The Monte Carlo optimisation of weights for all 11 items was performed for all $2 \leq$ MaxSelection ≤ 11 and was driven by an error function covering two aspects:

1) The derived index should "explain" the collected data with a minimum error function. An error is identified if the combination of items given by a participant for two consecutive points in time (now→5y or 5y→long term) would reduce the resulting digital score, thus causing a reversal in maturity.
2) The index should use weights that are evenly distributed over a given range (10-100). This was done to avoid "collapsing" solutions, where many aspects are weighted equally to avoid the

errors of the first criteria. Mathematically, the average difference between equally spaced items is equal to the total range divided by the number of items minus one (average difference = 90/(11-1) = 9). Overall, the sum of all squared differences between two adjacent factor weights and the average distance was minimised.

The matching process for the 205 ratings was repeatedly performed to rule out being captured in local minima. The convergence of the process was robust and resulted in the weights shown in table 2. Overall, both optimisation criteria were kept in balance to avoid clusters of weights and satisfy the experts expectation of an increase of maturity over time. The minimum of error 1 was 17 (for MaxSelection between 8 and 11) which corresponds to a fit in which over 90% of all expert judgements agree on the order of implementation of the items included in section 2.2. For smaller MaxSelections, the minimised reversal (error 1) rate increased (see tab. 2). This indicates the robustness of the process and in consequence the generic nature of the DMI.

Table 2: Optimised weights of the best result for various MaxSelections.

Max Selection	Cluster	Reversal Error	Distance Measure	Average Weight	V589	V590	V591	V592	V593	V594	V595	V596	V597	V600	V601
2	0	62	41	51,5	27	35	56	86	19	45	75	95	65	50	14
3	2	58	136	46,6	16	31	47	94	24	46	70	82	58	35	10
4	1	49	66	47,6	10	23	43	94	39	51	73	81	62	32	16
5	2	41	258	50,5	12	27	38	96	45	89	60	81	62	29	17
6	1	32	174	61,0	12	38	46	90	78	83	65	98	85	51	25
7	1	24	276	64,4	12	48	56	92	77	82	68	100	87	60	26
8	2	21	398	64,2	10	42	74	84	79	79	72	98	90	57	21
9	2	17	599	65,4	12	42	57	73	72	81	80	99	88	66	49
10	2	17	561	64,4	11	40	58	71	73	79	78	98	86	64	50
11	2	17	593	64,5	11	41	58	71	73	79	78	98	87	64	49
Stats	Cluster	Reversal Error	Distance Measure	Average Weight	Paper	Help	Online forms	No media discon-tinuity	Per-sistent data	Inter-faces	Data quality	Sam-pling	Parallel proces-sing	Roles and rights	Except-ions
Mean	2	34	310	58	13	37	53	85	58	71	72	93	77	51	28
StdDev	0,7	16,7	204,7	7,5	4,8	7,3	9,7	9,5	22,5	16,1	6,0	7,7	12,6	13,3	14,9
Min	0	17	41	47	10	23	38	71	19	45	60	81	58	29	10
Max	2	62	599	65	27	48	74	96	79	89	80	100	90	66	50

The best-fitting solutions were examined for plausibility and robustness. The standard deviation was calculated for each weight as an indicator. The observed variation was acceptable, thus the mathematical model converged to one stable solution.

The resulting digital score was validated by calculating the correlation with the overall digital score for the selected skill using the U-test (also known as the Wilcoxon-Mann-Whitney test). All calculated index values for the Maturity Ratings from (von der Heyde, 2022d) show a high predictability towards the overall judgements of the Dx Score evaluated in (von der Heyde, 2022a). The rating for the current status (Dx-now) and the expected digital status in five years (Dx-5y) can be predicted by any of the six newly calculated index values (DMI: done/future X now/5y/long term).

The backward prediction was more limited: Dx-now predicted DMI-future-now, and Dx-5y predicted DMI-done now/5y as well as DMI-future-now. Both correlations with the business capability ratings for implemented aspects (DMI-done) were weaker (e.g., measured by power) than the correlations with the business capabilities not yet transformed (DMI-future). All four correlations are consistent with the hypothesis that the Dx ratings collected in (von der Heyde, 2022d) measured those areas that were ahead of the participants rather than those that they had already implemented. The same was true of all the correlations between the individual Dx scores for each capability. Again, the situation was not assessed on the basis of the current situation of the areas changed by digital tools, but almost all indicators were correlated with the area for the business capabilities that will change in the next five years. Thus, the overall Dx scores assessed expected development rather than the current situation.

The calculated Digital Index for the different business capabilities showed, as expected, a high correlation in almost all combinations of the index. This is to be expected as the index is derived from the data with the assumption that the index will increase with additional (more advanced) digital measures.

Finally, the new index of digital maturity proved to be independent of the general characteristics of the participating institutions. No institutional measures (such as type and size) were correlated with any of the calculated indices.

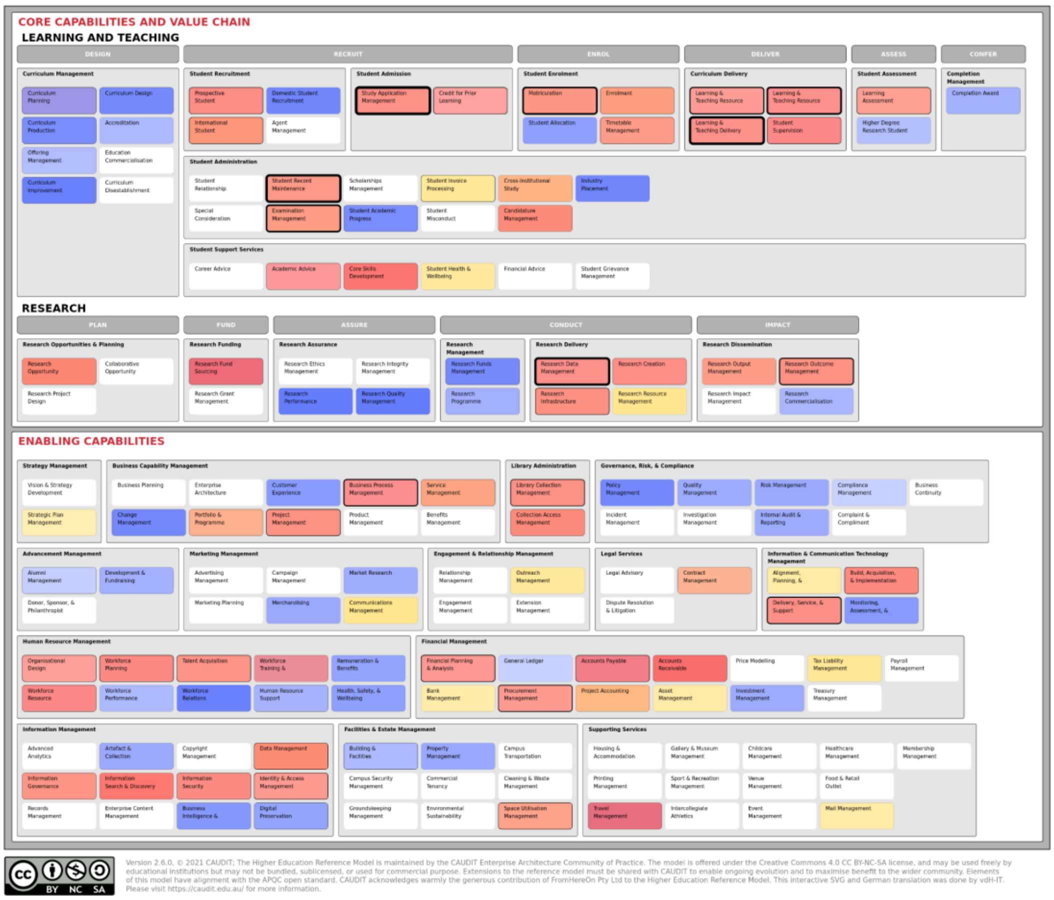

Figure 1: Heat map of the current digital maturity score based on the HERM business capability (BC) model using (von der Heyde, 2022b). The colour intensity is correlated to higher average digital maturity of the institutions for the specific BC. The yellow colour corresponds to BCs which had been previously developed by digital tools. The blue colour is used for BCs which have not yet been digitally changed, but which are expected to change in the near future. Finally, the red tones indicate a mixture for those BCs which have begun to change and will continue to do so. The more orange the tone, the higher the BC maturity of institutions previously changed is judged to be, and more violet colours indicate higher maturity judgements for institutions changing the BC in the future.

We conclude that asking about the selected items is more sensitive than a single overall judgement. The selected items may be able to distinguish more precisely between the current status and expected development. For example, it is useful to monitor the changes that institutions such as universities undergo as different measures are implemented. Overall, it is expected that the index, if applied consistently, will allow a fine differentiation between areas of the same institution, but also a comparison between institutions in the same sector.

3 Application to HERM Capabilities

The weights for the digital index were derived from the survey data (von der Heyde, 2022d) and heat maps were generated by the method in (von der Heyde, 2022b). As this dataset was also related to the business capabilities in which the digital score was assessed, the new index can be used to provide an overview of the survey data. For example, the best, the median or the mean weights can be applied to the data. Overall, the results are very similar across the large dataset. This also confirms the robustness of the proposed maturity index.

The resulting heat maps can be compared between the single score from the original survey and the newly derived digital maturity score. As the U-test confirmed a high correlation, the results look very similar. A new shape has therefore been chosen for Figure 1. The current state of digitalisation, as calculated by the Digital Maturity Index, was assessed for two conditions: a) for BCs that have already changed due to the intensive use of digital tools, and b) for BCs that were expected to change in the next five years due to the use of digital tools. Category a) BCs were coloured yellow if they were not selected for further change. BCs in category b) were coloured blue if they had not yet been changed by digital tools. A mixture, i.e., ongoing change, was observed for the red-coloured BCs. The colour intensity corresponds to the DMI. The shading changes towards yellow (resulting in orange) and blue (shown as purple) represents the mixture of previous and future digital modification.

4 Summary

Measuring the status and progress of digital transformation often seems to require a lot of effort and many subjective assessments. One must ask a lot of people about their views, collect an adequate amount of data, and statistically analyse it all.

The proposed Digital Maturity Index (DMI) dramatically simplifies the process. Overall, the key components of digital maturity are captured by 11 simple, fact-based, closed-ended questions. They are therefore often quick to assess. The index can even be collected in parallel for different business capabilities or processes across the institution with minimal effort.

Index items are derived from a list of requirements. The index weights were derived from a national survey on digital transformation in Germany. The index appeared to be robust to missing data such as unanswered questions. The results were checked for required correlations, e.g., with other recorded Dx scores, and also for non-existing correlations with institutional data such as size or type of university. Having been validated in this way, the index was applied to the remaining data from the survey to demonstrate the additional impact that a fine-tuned DMI can develop.

The numerical adjustment of the weights was carried out with data from only one sector. It is expected that other sectors will result in a different set of weights. However, the generic structure of the DMI allows for more specific items to be added as required or removed if obsolete. As the index focuses on the technological aspects, there is still further evidence required that other aspects, such as cultural change, customer experience or strategy, leadership and governance, etc., are nonetheless covered. However, as the correlations with the previously analysed Dx scores are very robust, a similar performance is expected.

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