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# A Framework For A Scoping Review Of Digital Transformation Of Engineering Education

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# A FRAMEWORK FOR A SCOPING REVIEW OF DIGITAL TRANSFORMATION OF ENGINEERING EDUCATION (RESEARCH)

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## ABSTRACT

The digitalization of engineering education has made significant progress in recent years not only due to societal circumstances such as COVID-19, but also thanks to technological development and progress and digital transformation of engineering education seems more imminent than ever. This paper presents the development of a framework and process for an ongoing scoping review regarding frameworks for digital transformation of engineering education. Empirical studies on digital innovations in specific small-scale contexts are numerous and the literature is rich. This study, however, aims to identify more systematic and holistic approaches to digital transformation. At this stage the review work has resulted in 21 research papers for full-text screening from 4 databases, SCOPUS, ProQuest, Web of Science, and Engineering Village. The proposed framework facilitates analysis of how frameworks for digital transformation of engineering education are informed and conceptualized ideologically in the sense of what digitalization should do for engineering education and how they guide and facilitate digital transformation. The framework builds on and combines theory from educational and digital transformation research and enables elicitation of essential elements of digital transformation in an educational context, including ideologies, models, dimensions, actors, elements, and levels of digitalization.

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## 1 INTRODUCTION

The promise of an imminent digital transformation (DT) of engineering education, and higher education, has lasted several decades at this point. In many ways we *have* digitalized practices in higher educational institutions at an organizational level, but when it comes to transforming education many of the potentials of digital technology are yet to be realized. Empirical studies on digital innovations in specific small-scale contexts, such as the classroom, are numerous and the literature is rich. In contrast, this study is interested in more deliberate, informed, or ideological approaches to digitalization asking and answering what digitalization should do for education and how. All the way back to 2007, Laurillard (2007) wrote that digital technology has merely been consigned to support traditional modes of education. This is to a large extend still true today. A blind eye has been turned to the transformational potential that digital technology can have in realizing the educational ambitions we have. In most cases digitalization of education has merely supported or replicated traditional modes of education. In this connection, some studies (e.g. Figlio et al., 2013; Shu & Gu, 2018) have found digital education inferior to traditional by e.g. comparing students' experiences of face-to-face lectures with online versions. Weller (2022) calls such comparisons and findings unfair and unsurprising. It is like comparing the live performance of theatre to seeing it on television. This type of digital education suggesting a 1:1 transfer of traditional pedagogy to digital versions has been especially prevalent in recent years of emergency remote teaching due to COVID-19 (Mseleku, 2020) for many reasons. For actual DT of education, and to avoid drawbacks of the 1:1 transfer, we need to move past digital replicas of traditional education and experiment with and explore the potentials and affordances of more native digitally and hybrid designed education. Such an approach might help us in realizing some of the many promises of DT and the ambitions we have for engineering education. The technology for DT is mature and ready – are we?

This paper will present the process and development of a framework for an ongoing scoping review that aims to uncover the body of literature within engineering education research that can help us take such steps i.e., systematic, and holistic approaches to DT of engineering education. By combining educational research with Kræmmergaard's 5-stage DT model (Kræmmergaard, 2019), the framework will enable us to identify relevant frameworks of DT and classify the type of transformation and level that they aim to facilitate.
The framework helps to elicit answers to how frameworks for DT of engineering education are informed and conceptualized ideologically in the sense of what digitalization should do for engineering education and how they guide in terms of how transformation can be facilitated.

## 2 METHODOLOGY

The research objective of this paper focus on examining frameworks for DT of engineering education including their key characteristics. For such a purpose, Munn et al. (2018) suggest the scoping review as the most appropriate. Scoping reviews differ from systematic literature reviews in that the latter typically seek to answer precise questions, with defined methodologies (O'Flaherty and Phillips, 2015), whilst the former has a more exploratory purpose of e.g., clarifying key concepts, examine

how research is conducted on a specific topic or field, or to identify key characteristics related to a concept (Munn et al. 2018). Often scoping reviews are utilized in preparation for an actual systematic literature review to determine whether a complete systematic review is necessary (Munn et al., 2018; O'Flaherty and Phillips, 2015). In this connection, scoping reviews may help to develop and confirm e.g., relevant inclusion criteria and analytical themes in relation to a specific concept, which is also the purpose of this paper presenting the framework of the scoping review.

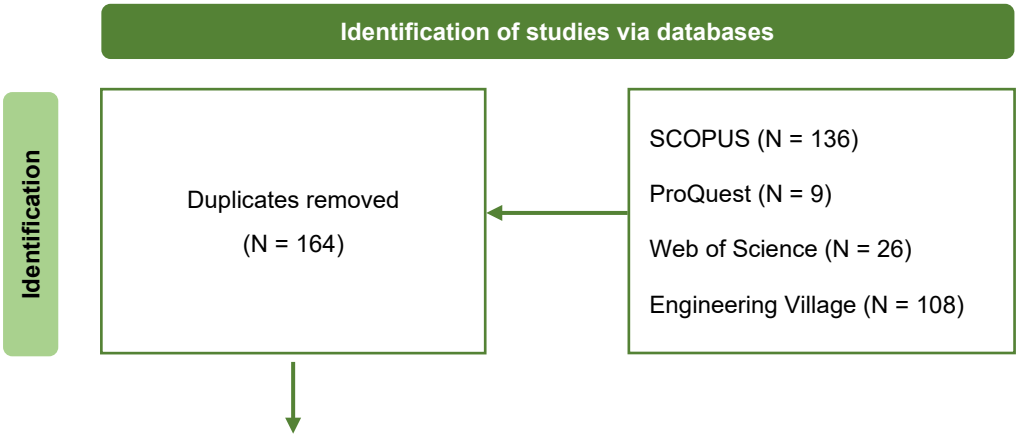
Based on the aim of this scoping review a set of criteria for inclusion was developed. (1) Selected research must be peer reviewed and either of the type of conference paper or journal article and written in English. (2) The context of the research must be within engineering education. (3) The research must have an educational and/or pedagogical focus. (4) The paper must present a clear framework for DT above classroom level. This set of criteria guided the reviewers screening. The included databases count SCOPUS, ProQuest, Web of Science, and Engineering Village. The final search string that was executed March 2023 can be seen in table 1 below.

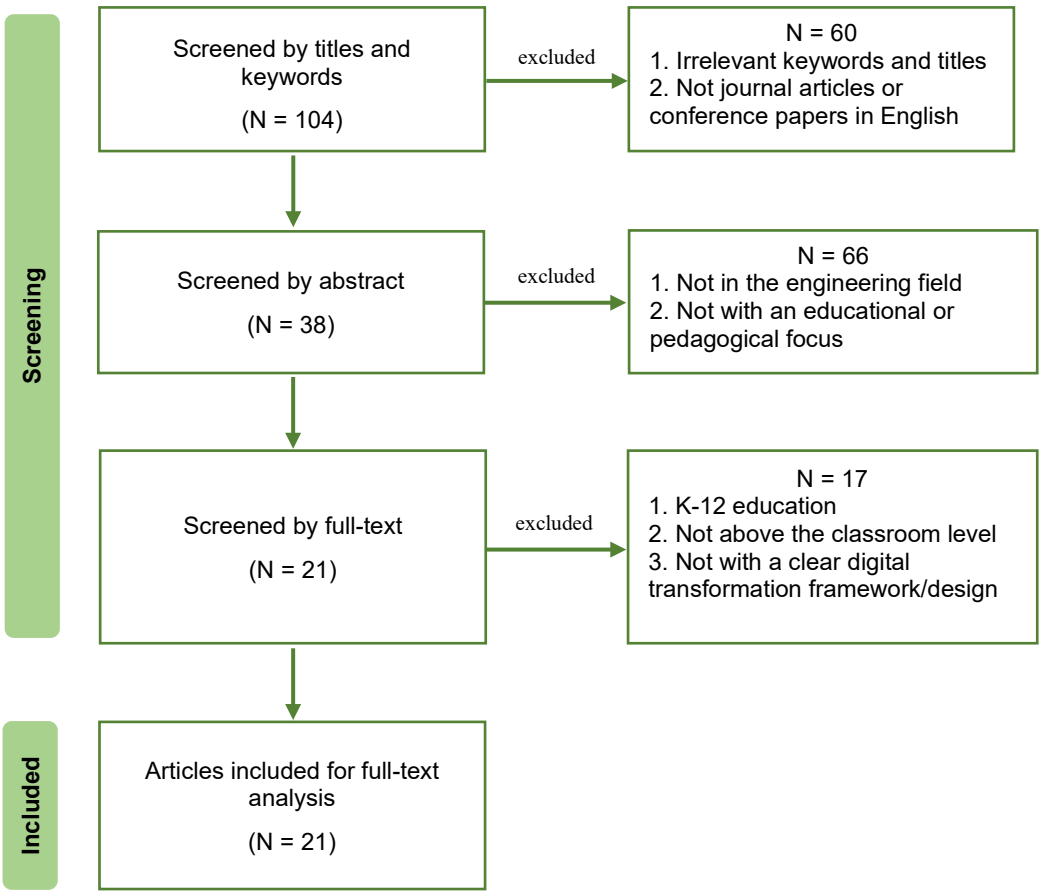
**Table 1**

| | | | | |
|---|---|---|---|---|
| "engineering education*" | AND | Digital transform* OR Digitally transform* | AND | Framework* OR Model* OR Design* |

As can be seen from the PRISMA chart in table 2, the search result produced 164 items for further screening after removal of duplicates across databases. Screening was initially based on title and keywords, which excluded 60 items, and then secondly based on abstract, which removed further 66 items. Finally, a full-text screening excluded an additional 17 items. In the end, a total of 143 items were deemed irrelevant and excluded for various reasons related to the inclusion criteria as can be seen in the PRISMA chart. For each step in this process, the authors ensured a common understanding by random control checks of the same papers and thereby minimizing researcher's bias (Munn et al., 2018). This resulted in a pool of 21 papers which will undergo full-text analysis in the final review.

**Table 2**






## 3 THE FRAMEWORK AND PRELIMINARY RESULTS

### 3.1 The framework

This section will describe the development of the analytical framework. First, as a central concept for the review, a definition of DT is important, which will be followed by the analytical themes of the framework.

Kræmmergaard (2019) developed a 5-stage DT model for industry and public institutions, that describes the most basic implementation of IT at stage 1 to full DT at stage 5. This classification is essential to the analysis of the identified frameworks and will therefore be shortly presented in the following. We will contextualize the stages to DT of engineering education by adding examples to Kræmmergaard's work.
Stage 1 and 2 is popularly described as electrifying existing work practices and processes for the purpose of efficiency and economy gains. At stage 1 support of existing practices and services with IT is key. Digital technology has a supportive role and allows users to help themselves by e.g., accessing supporting material or finding the class schedule in learning management systems. At stage 2 there will be a standardization of systems. Digitalization strategies are formulated centrally at the leadership level and focus is on implementing new technology for the purpose of streamlining. Work practices and processes still need to adapt to technology rather than the other way around. An example of this could be during COVID-19

lockdowns, where various digital tools, e.g., tools for video conferencing and online whiteboards, quickly became standardized, and teachers had to adapt practices to those platforms with all the constraints that follow. From stage 3 and up, digital technology is a central part and co-creator of the educational practice and experience. Focus is on rethinking core practices and processes in a digitally native manner. Digital replicas of e.g., face-to-face lectures using Zoom are no longer enough. At this level, staff and students need to explore and take advantage of the new affordances that digital technology can provide. Stage 4 is where the organization will challenge itself to rethink its own core services through digitalization. Previous assumptions of what "good" education should be are challenged. There is a seamless integration of systems, which could be used for e.g., collecting learner analytics and create more personalized learning experiences. At stage 5, technologies such as AI, machine learning and AR/VR are widespread and well-integrated to search for and create new patterns and opportunities in combination with human decision making.
To guide the coding and analysis we, the authors, discussed initial themes based on the aim of the review and Kræmmergaard's framework, which were then shared and discussed with colleagues in our research group. The final pool of papers included in the review are to be mapped and analyzed according to this codebook with different themes. For mapping purposes demographics categories were also created. This process resulted in the codebook seen in Table 4 below filled in with information from an example of a random paper from the current pool of 21 papers.

**Table 3**

| Country | Year | Type of publication |
|---|---|---|
| Moldova | 2021 | Conference proceedings |

| Discipline | Level of education | Stated pedagogic model(s) | Digital tools | Level of educational organization | Digitalized learning activities/elements | Educational/ pedagogical focus | COVID-19 reaction |
|---|---|---|---|---|---|---|---|
| All engineering disciplines | All semesters | Distance education | Remote and simulation labs, Teams, Moodle, online video platform | Institutional | Remote lab, simulation lab, interactional analytics, assessment activities, LMS, online video lessons. | Yes | Yes |

| Underlying drivers and/or ideologies | Framework focus | Clear, guiding, holistic framework? | Organizational levels involved and actors | Digitalization form | Level of digital transformation |
|---|---|---|---|---|---|
| Risk mitigation (against lockdowns), employability, marketization | Entangled | Yes | Institutional level | Content, cognitive, emulation, interaction, creation | Gen. 4 |

Some of the themes are descriptive and answers are easily elicited from informational text in the papers. This is true for the first row of table 4, colored lighter shades of green. They include demographics information for mapping purposes, i.e. *country; year;* and *type of publication.* Second row, green color, include contextual information such as *discipline; level of education; stated pedagogic model(s); digital tools; level of educational organization; digitalized activities/ elements; use of pedagogic or educational research; and COVID-19 reaction (whether the DT happened during or as a response to COVID-19 lockdowns).* These themes will mainly answer the "what-, when- and where-questions".
The remaining themes in the third row require holistic analysis to elicit an answer from the text, either because it is not clearly stated, or because a higher level of complexity. These are colored in dark green and include the themes *underlying drivers and/or ideologies (UDI); framework focus (FF); clear, guiding, holistic framework (CGHF); organizational levels involved/actors(OLIA), and type of digitalization (TD)*. The *UDI* theme will elicit values and beliefs underlying actions towards DT. Examples could be employability, marketization, accessibility and inclusion, reducing vulnerability (e.g. to lockdowns), better learning gains, sustainability etc. *FF* can either be technological, pedagogical or entangled. Fawns (2022) described how discourses and implementations of digitalization have been plagued by deterministic ideas, where either technology or pedagogy are dominant. This might be reflected in frameworks for DT. Fawns advocate for an entangled understanding, recognizing that technology and pedagogy cannot be handled as separate, isolated phenomena. This is also central to the upper-levels of Kræmmergaards's framework, where digital technology is no longer regarded as supplementary but as integrated and entangled with general practices and processes. *CGHF* is an important theme in terms of the possibility of analyzing the intentions and scope of the framework. In relation to this, *OLIA* will report roles and actions by different actors in different organizational levels. In relation to the Kræmmergaard framework, this is important, as she describes DT develops from being localized, to centralized, and finally more towards decentralization through the stages. Finally, TD will capture different types of digitalization, divided in digitalization of content, cognitive facilitation, emulation (VR/AR), interaction, and creation (e.g. AI). These are based on basic affordances of learning (Chi, 2009; Laurillard 2013) and Kræmmergaard's description of advancement in the use of complex technology throughout the stages.
Together, the themes give data for a holistic qualitative analysis to answer the "how- and why-questions" of DT processes, i.e., why we choose to transform engineering education through digitalization and how engineering education is transformed through digitalization. It will also be possible to classify the level of DT that each framework aims to facilitate based on the Kræmmergaard framework.

The current themes will guide the initial coding and then be summarized together with themes that emerge through the open-coding method (Creswell, 2012) for further development of the framework.

## 4 DISCUSSION AND SUMMARY

The basic assumptions of how DT can be facilitated, and for what purposes we pursue DT, take part in forming the future of engineering education. However, institutional strategy documents, providers of digital technologies and other stakeholders rarely declare understandings, ideological drivers, or value statements in relation to DT, which makes it challenging to deduce the logics and drivers of DT. Thus, it is not always apparent how frameworks of DT are informed and imply specific understandings, purposes and directions for education. By interrogating frameworks of DT using the presented framework these will become more visible and comparable enabling stakeholders to have more informed reflections and decision processes. Furthermore, the adaption of Kræmmergaard's framework enables identification and description of certain indicators and enablers of DT and general characteristics of stage 3 and above transformations in a higher educational setting. It will be of interest to analyze future results regarding what are the drivers of such DT frameworks, the digital technologies implemented, and the types of digitalization in relation to learning.

This paper has presented the process and development of a framework for an ongoing scoping review of DT of engineering education. The search strategy and current screening process have resulted in 21 full-text papers for full-text analysis. The framework conceptualizes DT in an engineering education context based on educational and DT research and will generate rich data to create a state-of-the-art overview of DT frameworks within engineering education. The framework can be of use, or inspiration, for studies in other educational contexts as well and findings could be compared and discussed with other reviews of DT in higher education to single out unique traits of engineering education.

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