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Learning engineering: Past, present and future[1]

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Highlights

- Learning engineering is not about technology, it's about problem solving in support of learning.
- Following the developments in the field of educational technology, a new type of expert, an educational engineer, will emerge.
- Other engineers create better living environments, learning engineers create better learning environments.

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Keywords: *Learning engineering, history, process and practice, education.*

Abstract

Learning engineering is a term and combines the process and practice that applies the sciences of learning using human-centered engineering design methodologies and data-driven decision making to support learners and their development. This term is about problem solving and aims to support learners and their development. In line with the indicated highlights and the aim of the term, this editorial study aims to investigate the history of the learning engineering. Accordingly, the study is structured into three sections: While the introduction part over the past and present perspectives of the learning engineering, the second part is constructed as follows: (1) definition of learning engineering (2) key components of learning engineering (3) instructional design in learning engineering (4) benefits of learning engineering (5) challenges and considerations (6) future of learning engineering. Finally, the conclusion and suggestion part is focused the role of learning engineering in the forthcoming era.

1. Introduction

1.1. History: Past and Present

John Dewey, in his 1922 article "Education as Engineering," first articulated the conjunction of the concepts of education and engineering (Dewey, 1922). According to Dewey, education, being dependent on habits that emerged before the scientific method, represents the dominance of thought by the inertia of ancient traditions rather than fostering critical thinking. He contends that in the absence of pioneering developments, the existing science of education cannot progress education in schools.

Dewey, recognizing the need to break free from this vicious cycle, discusses the necessity of educational engineering and poses the question, "How will educational processes take on a form of structural engineering?" However, he notes that at that time, society was not ready for such a change. He states, "There is no art of educational engineering. There will be no such art until important progress is made in creating new forms of education at home and in school. (p.91)" Dewey emphasizes that until significant

[1] This study is derived from the presentations of the panelists who defended the "it is possible" side in the opposing panel event titled "Learning Engineering: Is It Possible or Not?" held at ICETOL on 20-23 June 2023, in Cunda, Ayvalık.

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advancements are achieved in developing innovative forms of education, the art of educational engineering will not come into existence.

The question of whether there could be a field called "educational engineering" has been brought up from time to time later on. For example, in his article "Is there a field of Educational Engineering" written in 1945, Charters discussed the existence of the field of educational engineering and claimed that it couldn't be prominently highlighted due to the reservations of existing educators about embracing such a change critically (Charters, 1945).

In 1967, Nobel laureate Herbert A. Simon, in his article titled "The Job of College President" written at Carnegie Mellon University, expressed the necessity of learning engineering, particularly in higher education. He stated, "There is no simple path that will take us immediately from the contemporary amateurism of the collage to the professional design of learning environments and learning experiences. There are, however, some obvious first steps along the way. The most important of these is to find a place on campus for a team of professionals in the design of learning environments--learning engineers" (Simon, 1967, p.77). Herbert Simon emphasized the need for individuals working collaboratively with faculty in universities, specifically in the position of learning engineers. These professionals would collaborate with faculty members to design learning experiences in specific disciplines, facilitating educators in gaining a deeper understanding of learning.

In this regard, Turkish researcher Cevat Alkan has made observations in his book titled "Educational Technology." Alkan (2011) claims that, following the developments in the field of educational technology, a new type of expert, an educational engineer, will emerge.

Before proceeding further, it would be beneficial to clarify the concept of engineering. In its most general definition, engineering is the application of science to solve problems. Engineers are those who apply the discoveries of scientists to the real world. The English term "Engineering" has its origin in the Latin word "ingenium," meaning "innate quality, especially mental power, and therefore clever creativity." Engineering, which is essentially the discipline that creatively solves problems, is often inadequately associated only with tools, devices, and machines. Engineers commonly encounter (such as civil or mechanical engineers) create more effective, efficient, and satisfying living environments. In the process, they may utilize certain tools and technologies according to their fields, but ultimately, they provide a solution to a problem. This could be a comfortable, safe, and economical car or house.

Similarly, the realization of more effective, efficient, and satisfying learning has become a problem to solve in recent years. The need for a field called "learning engineering" has been highlighted to address how such learning can be achieved. To illustrate, in the field of basic sciences, research in chemistry may reveal laws and principles, but it is the field of chemical engineering that applies them to practice. Scientific fields related to education and learning can similarly unveil principles or findings, and the task of implementing them in practical applications falls under the domain of learning engineering.

John Dewey's call for a radical overhaul of the education system in 1922 is being discussed more extensively in contemporary times. Achieving such a transformation seems to require a radical revision, almost a reversal, or a paradigm shift. As Dewey pointed out, education often involves doing old things with new names. Could learning engineering be a crucial part of the solution for breaking out of this cycle and transitioning to a system that meets the needs of the current era, as Dewey suggested? This article aims to provide a brief introduction to the topic and serve as a starting point for future discussions that will unfold

Researchers who take a critical stance on this issue express that a field like learning engineering may not be possible or is unnecessary. In this article, criticisms will not be addressed; instead, the focus will be on what learning engineering is and why learning engineering should exist. Counterarguments are expected to be addressed in other writings.

2. Learning Engineering in Education: Process and Practice

- ***Definition of Learning Engineering:***

In the teaching and learning edition report of 2020 EDUCAUSE Horizon, it is stated the learning engineering is the field which emerged from the space of digital learning, and has attracted the attention of higher education and industry. According to the report, learning engineering is "an evolving field that focuses on how engineering methodologies can inform and improve learning technologies and related architectures." (EDUCAUSE, 2020, p. 24). The similar view is taken into consideration by Wagner (2019) that underlines the importance of making the learning and development ecosystem up is vital to be known by digital learning professionals working across institutions, enterprises, and agencies to catch the trends and followed up. Since learning is a complex area and required to be specialized with the engineering and development expertise, and engineers are working in the development of learning technologies increasingly to benefit from a background in learning science and pedagogy, the felled gap is required as an intersection area. The intersection area consists of the data science, computer science and learning science, and holistically called as "learning engineering".

IEEE ICICLE (International Consortium on Learning Engineering) (2019) stated that learning engineering is a process and practice that applies the sciences of learning using human-centered engineering design methodologies and data-driven decision making to support learners and their development. It is a set of "Processes" and "Practices" that aim to support learners and their development when the purpose and concept of learning engineering is examined in detail. As stated by Goodell, Kolodner and Kessler (2023), "Learning engineering is not about technology, it's about problem solving in support of learning. (p. 18). In line the explanations, it is possible to assert that the concept of learning engineering incorporates the different expert fields to provide advance learning with the new developed and emerged tools in both process and practice professionally and inter-disciplinary.

Learning engineering is a crucial concept that breaks away from other models in capturing the spirit of the time and collaborates with many disciplines from the past to the present and even to the future. Lee (2023) states that the basic assumption underlying learning engineering is that the large amount of digital data to be collected through new learning platforms and used as part of the continuous improvement cycle is uniquely new and powerful. According to this, if it is needed to evaluate the issue of designing collaborative learning experiences with certain disciplines in the context of "Process" and "Application";

o In process, a field focused on technologies for learning engineering design methodologies and how the associated architecture can inform and improve

o In practice, a new field that can be the basis for changes in the application of learning science, which is based on an interdisciplinary approach benefiting from data science, computer science and learning sciences (Erb, Garg, Wagner, & Goodell, 2019).

- ***Key Components of Learning Engineering:***

The field of learning engineering, defined by Kessler and IEEE ICICLE Design SIG. (2020) and is seen an applied learning sciences. According to the definition it is understood that learning engineering contains different fields and key components to be applicable for learning sciences. At that point, a brief case study titled "The 7 Things You Should Know About Learning Engineering" (Wagner, Barr, Blake-Plock, Robson, 2018) may help while having an insight view into the components of learning engineering. Especially in the second phase of the things the answer of "How does it work?" supports that learning engineering has a potential to provide advanced learning and optimize learning by working with many different disciplines. It uses data, computer and learning sciences to focus and enable the development of teaching methods, techniques, strategies and materials. Furthermore, learning engineering uses data science in processing with learning analytics, educational data mining, machine learning, bibliometric/scientometric etc. techniques/methods for the unique types of data obtained from educational environments. Similarly, learning engineering uses computer science to integrate instant data obtained from the learner and his/her environment through human-machine interaction with various algorithms. Learning engineering, which is at the center of the interdisciplinary approach as an understanding brings learning sciences into practice with software engineering, subject matter expertise, assessment, measurement and evaluation, education and training professional practices, learning environment engineering and instructional design/learning experience design, etc. It requires being a team with areas of expertise. With the competence of the team, each member focus to operate continuously for a data-based evaluation and improvement process to optimize learning in collaboration. The dynamic cycle is important for both the instructional design and learning experience design.

Therefore, students, resources and the cultural environment in which the problem will be solved should be taken into account. The problem to be solved determines the human resources to be selected in the next step of the process. While some problems can be solved by a single person with a wide range of skills; some problems need to be solved by a team of professionals with deep expertise in various fields as seen in Figure 1, below.

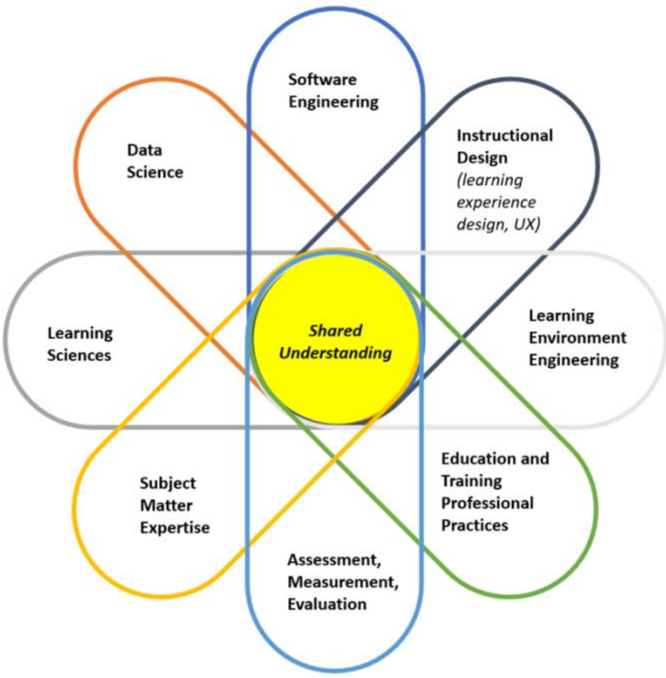

Fig. 1. *The Learning Engineering Process – Establishing LE Team (Kessler et. al. 2020).*

As seen in Figure 1, the team should collaborate to design, produce, and implement workable solutions. In this direction, human resources are created as needed from the different discipline areas. The Figure 1 can be interpreted within the discussion of Lee's (2023) article whether there is a natural or artificial distinction between "learning sciences" and "learning engineering"? Although the nature of that connection has not stated clearly in the article, incorporating the different expertise fields during the learning engineering process would be entirely connected to the work of learning sciences, and learning research that has resided in experimental studies would be the process of learning engineering team's ecosystem. The vision and understanding shared within the different expertise field may contribute to personalized learning experiences with the basis of data-driven decision making. Data is very important in the learning engineering concept, which is known to start from the space of digital learning. It should not be forgotten that each of the footprints obtained from the interactions of learners in the digital environment, both with themselves and with the learning environment, will contribute to the decision-making process together with learning analytics. Processes such as predicting learner retention in higher education institutions, analyzing learner behavior and improving learning processes with personalized feedback are called learning analytics which is also under the shared mission of the learning engineering and supports the learning theory in line with including the practices.

In line with the learning theory and engineering; it is possible to incorporate the both framework under the learning engineering with the explanations of Erb et al.'s (2019) which focused infrastructure and cooperation of the learning engineering that can operate a data-based decision-making mechanism with critical data. According to these explanations, the critical data can be obtained in applications in the process. The importance of obtaining critical data in terms of learning theory is important from an engineering perspective. Baker and Boser (2021), express this importance of it with the following statements:

"There is increasing interest in developing the discipline and practice of learning engineering to improve student outcomes. Learning engineering combines scientific knowledge and theory on learning, and applies a rigorous combination of theory, data, and analysis to develop and improve educational systems and methodologies to produce enduring, high-quality learning." (p.3).

Hence, without course correction, most adopters of learning engineering will pursue, at their own risk, efforts to improve technology-supported learning in ways that neglect the full and necessary scope of what has already been discovered and continues to be discovered in the learning sciences (Lee, 2023). Although there has been a recent trend in learning sciences about what is important to learn and for what purposes; it is everyone's duty to consider extremely fundamental questions. At this point it is important to have a connection with learning sciences and learning engineering. The article discussed by Lee (2023) underlines that learning engineering is truly focused on modern computational technology ecosystems but learning sciences is not. Hence, it could be noted that, rather than belonging to a group; it is thought that focusing on what can be done together with other groups may be a good idea to improve the learning sciences and the environment. Learning engineering process has clearly pointed that sense with a shared understanding with the different groups and/or disciplines in a team, as seen in Figure 2 within the context of a problem and the solution way, not about a technology but about a problem solution.

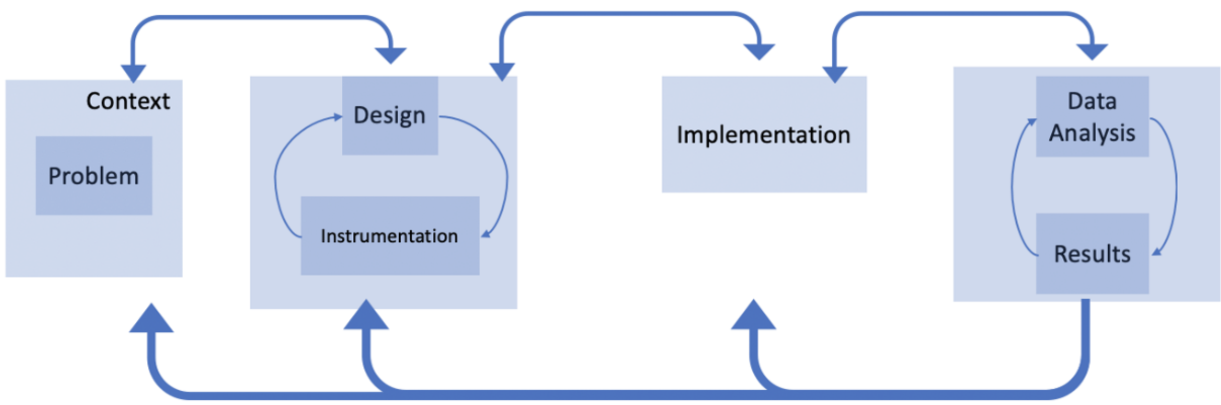

Fig. 2. *The Learning Engineering Process (Kessler et. al. 2020).*

According to Kessler and IEEE ICICLE Design SIG (2020), regarding learning engineering, the first step is claimed as defining the problem to be solved and the contextual environment in which this problem occurs as seen in Figure 2. Then, data could be collected throughout the application with designed instrumentation. In the data analysis and conclusion step, the data is analyzed together with the results related to other data analyses. This entire evaluation process provides information about understanding the problem and its solution. Insights from assessment feed, inform, and help identify problems and the iterative solutions used to address them.

- ***Instructional Design in Learning Engineering:***

The instructional design is originally claimed by John Dewey as the development on the "interlinked science" between learning theories and educational practices which is also known as a discipline and called as "Instructional Design (ID)", "Instructional System Design (ISD)" or "Instructional Science" (Reigeluth 1983; cited in Paquette, De La Teja, Léonard, Lundgren-Cayrol, and Marino, 2005). Considering all the definitions, the term's concept brings a combined different expert fields to the minds especially for increasing the effectiveness of the teaching and learning process. The explanation of Wagner (2021) for the instructional design is quite clear as follows "instructional design described a practice of creating lessons and courses." (p.2). However, for the Instructional System Design the defined explanations for so many learning experiences are addressing bigger contextual and broad condition. On that side, the instruction is considered as a component in the established process model which is managed. It is worth to underline the distinction between the definitions in that manner "how learning engineering enhances the design and delivery of educational content?"

Accordingly, definitions provide support for the common denominator of learning engineering. Learning engineering places a strong emphasis on aligning instructional design with clearly defined learning objectives. This ensures that every component of the learning experience contributes directly to the desired educational outcomes. The instructional design process in learning engineering adopts a learner-centered approach. It considers the diverse needs, preferences, and prior knowledge of learners, aiming to create engaging and meaningful learning experiences that resonate with the target audience.

In this context, while instructional design could be related with a set of created described activity for a lesson or a course; learning engineering focuses on using data analytics obtained from the lesson or course environment in line with the computer-human interaction by modeling the inputs and measuring the outcomes for a sustain and continuous learning to ensure the quality assurance. It is also possible to assert while the learning engineering focus to improve the designed instruction to optimize and improve with the systems of learning decision-making; baseline and formative evaluation processes are also valuable in terms of the quality of the education.

- ***Benefits of Learning Engineering:***

The concept of learning engineering is defined as applied learning sciences (Goodell, Kessler, Wiltrout and Avello, 2021). This definition includes some clues for the benefits of learning engineering in many perspectives. Especially with the basis of key concept of learning engineering which combines methods such as Learning Analytics and Educational Data Mining with design-based research to a better understand which teaching strategies enable optimal learning (Goodell, Kolodner & Kessler, 2023) is a closer conduction for its beneficiary. Inline the Goodell et al.'s (2023) statement that learning engineers design adaptations and variations to fit real people and sometimes even the needs of individual students is bringing the beneficent of the term into the teaching and learning environment. The following can be listed as some major benefits of Learning Engineering:

Improved Learning Outcomes: Learning engineering facilitates the development of personalized and adaptive learning experiences.

Efficiency in Education Delivery: Automation of administrative work, grading, and content delivery allows educators to focus more on personalized interactions with students, fostering a more efficient and effective learning environment.

Adaptability to Diverse Learner Needs: Through data analysis and feedback mechanisms, it is possible to identify individual needs and adjusts instructional methods to provide a more inclusive educational experience.

Continuous Improvement through Data Analysis: Learning engineering relies heavily on data analytics to assess the effectiveness of instructional strategies. Continuous monitoring and analysis of learner performance data enable educators to make informed decisions, refine teaching methods, and adapt content in real-time, contributing to ongoing improvement.

Optimized Resource Utilization: Learning engineering helps optimize the use of educational resources, such as the efficient allocation of time, personnel, or technology. It ensures that resources are maximized, minimizing waste and enhancing the overall cost-effectiveness of education.

- ***Challenges and Considerations:***

The digital environments' problems, especially in teaching and learning, bring consideration as well as the challenges. Especially, the problems on a sustain and continuous system to enhance the quality of teaching and learning is at the fore. There is an urgent need for an ongoing evaluation and refinement. However, it is worth noting the resistance, internal and external barriers, conditions etc.

Resistance to Change: Introducing learning engineering may face resistance from educators accustomed to traditional teaching methods.

Validation of Learning Analytics: While learning analytics plays a crucial role, ensuring the accuracy and reliability of the data is a challenge. Validating the effectiveness of predictive models and analytics tools is an ongoing process that demands a robust framework for assessment and continuous improvement.

Resource Constraints: Implementation of learning engineering may be resource-intensive, requiring investments in technology, training, and ongoing support.

- ***Future of Learning Engineering:***

Considering the focus of learning engineering and its key components as data analytics, human-computer interaction, modeling, measurement instrumentation and continuous improvement (Wagner, 2021), it is necessary to combine scientific knowledge with application and data to ensure permanent, high-quality and efficient learning, and to develop and improve education systems and methodologies in learning engineering for a future based stage.

In that sense, for the future of learning engineering, Baker and Boser's (2021), summarizing of the ten basic opportunities for optimizing the field of learning engineering could be a road map for including at a high level of teaching and learning processes and applications: (1) enhancing R&D infrastructure in widely deployed platforms, (2) bringing learning engineering to domain-based education research, (3) building components to create next generation learning technologies faster, (4) enhancing human-computer systems, (5) better engineer learning system implementation in schools, (6) improving recommendation, assignment, and advising systems, (7) optimizing for robust learning and long-term achievement, (8) supporting learning 21st century skills and collaboration, (9) improved support for student engagement, and (10) designing algorithms and learning systems for diversity and equity.

The learning engineering ecosystem, used as an interdisciplinary model, has been carried out in some institutions. For example, within the scope of "The Simon Iniatitive" center established within Carnegie Mellon University in 2014, covers many areas such as training data, data mining, machine learning, computer-supported collaborative learning, virtual peer, educational games, neural basis of learning, causal learning, development and learning. Northwestern University also emphasizes the field of activity in learning engineering, as stating that "just as engineers use science and technology to solve problems, learning engineering blends pedagogy and cognitive science with educational technology to solve problems related to learning and teaching." (URL 1). Converting classes into online classes, making and evaluating large program designs, and providing consultancy for long-term technology initiatives and faculty development are also examples of the field's applications. Similarly, Boston College "Learning Engineering Master's Program" is a program (URL 2) that educates students with the interdisciplinary knowledge and technical infrastructure of learning engineering that offers students interesting, accessible and applied learning experience designs that benefit from the most up-to-date learning technologies and pedagogies. Carnegie Mellon University's Master of Science in Educational Technologies and Applied Learning Science program is an interdisciplinary program that trains students to become learning engineers and learning experience designers. The program applies the science and principles of learning, evidence-based research, qualitative and quantitative cognitive task analysis, and data-driven methods to design, create, and develop educational resources and technologies. NIIT (National Institute of Information Technology) University has also had the "Learning Engineering Principles and Practices" course since 2009. So, these examples may show that there will be more academic programs on Learning Engineering in the near future.

3. Conclusion and Suggestions

The terms "education as engineering" and "learning engineering" have been in use for nearly 100 years. Today, this perspective signifies the growing importance of learning engineering, both as a professional practice and an academic discipline. In alignment with the evolving landscape of education, Learning Engineering is emerging as a transformative discipline. Similar to how traditional engineering shapes physical structures like bridges and cars, Learning Engineering endeavors to design the framework of modern learning through the systematic application of evidence-based principles and methods in educational technology, learning sciences and engineering. Utilizing data and technology, it aims to engineer personalized, efficient, effective, satisfactory, and accessible learning experiences that cater to the unique needs of each learner.

Learning Engineering incorporates both traditional and cutting-edge technology, from artificial intelligence to immersive encounters, enhancing engagement and comprehension. Positioned at the intersection of learning science, learning technology, and instructional design, Learning Engineering represents a departure from the traditional one-size-fits-all model, ushering in a dynamic and personalized approach to learning. By leveraging advanced technologies, it creates adaptive learning environments where artificial intelligence algorithms analyze each student's progress, strengths, and weaknesses to tailor educational content accordingly. With a focus on evidence based decision-making, this field empowers educators to refine their teaching methods, ensuring the optimization of every learning experience.

Traditional classrooms will persist, but they must undergo transformation. Blended learning environments will offer students a seamless integration of in-person instruction and online resources. Learning Engineering ensures a smooth and cohesive transition between the two, acknowledging the diverse needs of students. Intelligent tutoring systems and AI-driven chatbots will assist students in navigating challenging subjects, offering instant support for inquiries. Immersive technologies, such as virtual and augmented reality, will revolutionize the learning experience. Learning Engineering goes beyond course design; it aims to craft immersive and captivating learning journeys. These technologies will render intricate concepts tangible, enabling students to cultivate a deeper understanding and retention of the subject matter. Automated processes will handle routine administrative tasks, enabling educators to prioritize teaching and mentorship.

Learning Engineering demonstrates a profound commitment to ethical considerations, safeguarding data privacy, mitigating bias in AI algorithms, and promoting accessible education for everyone, regardless of physical or cognitive abilities. This dedication to ethical principles, interdisciplinary approaches, inclusivity, and lifelong learning paves the way for a realm where knowledge knows no boundaries. Learning Engineering not only nurtures individual growth but also promotes collaborative learning and the effortless sharing of knowledge across global borders, making education universally accessible. Its goal is to shape a future where education is a dynamic, continuously improving journey that is meticulously engineered for precision.

The increasing demand for skilled professionals implies that learning engineering is poised for additional development as an academic discipline. This advancement underscores the importance of intensifying research efforts to delve into the meanings, definitions, and practical applications of learning engineering. As the field expands, there is a requirement for the creation of more comprehensive policies, regulations, and standards. Experts in this field will play an active role in pinpointing successful engineering methodologies and strategies for creating better learning solutions for learners, potentially collaborating to establish professional communities and avenues for continuous professional development.

In the forthcoming era, Learning Engineering will transcend being merely a profession; it will emerge as a force for positive transformation in the realm of education. It will encapsulate the commitment to a future of learning that is not only brighter but also more accessible and inclusive, promising a paradigm shift in the educational landscape.

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