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Approach to introduce sustainable intelligent products by means of collaborative data intelligence considering the digital twin

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Abstract

The early involvement of experiences gained through intelligence and data analysis is becoming increasingly important in order to develop new products, leading to a completely different conception of product creation, development and engineering processes using the advantages that the dedication of the digital twin entails. Introducing a novel stage gate process in order to be holistically anchored in learning factories adopting idea generation and idea screening in an early stage, beta testing of first prototypes, technical implementation in real production scenarios, business analysis, market evaluation, pricing, service models as well as innovative social media portals. Corresponding product modelling in the sense of sustainability, circular economy, and data analytics forecasts the product on the market both before and after market launch with the interlinking of data interpretation nearby in real-time. The digital twin represents the link between the digital model and the digital shadow. Additionally, the connection of the digital twin with the product provides constantly updated operating status and process data as well as mapping of technical properties and real-world behaviours. A future-networking product, by embedded information technology with the ability to initiate and carry out one's own further development, is able to interact with people and environments and thus is relevant to the way of life of future generations. In today's development work for this new product creation approach, on one hand, "Werk150" is the object of the development itself and on the other hand the validation environment. In the next step, new learning modules and scenarios for trainings at master level will be derived from these findings.

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1. Introduction

Intelligent products, which have been developed over several generations and are able to network and collect data during their life cycle as well as use phases communicating with each other, will increasingly conquer the markets. Consequently, introducing a new learning module into study curricula using learning factories is necessary to provide future experts with knowledge on the end-to-end engineering of such products and their interconnectivity throughout their life cycle. Addressing events across generations and the increasing needs of customers and products that communicate with the environment require an integrated product development process. However, current product development processes indicate that the product development and the production system are not interconnected with each other, which impedes the easy exchange of the necessary data for the realisation of an intelligent product [1]. In addition, existing approaches to product development and design throughout the product lifecycle such as VDI 2221, VDI/VDE 2206, among others, do not deal with the topic of intelligent product development [2,3]. This paper introduces a novel stage gate process according to the RFLP PPR-principle [4] that considers the multilayer phases of an integrated product development process (e.g. IPEM) [5] as one of the essential building blocks for study curricula using learning factory.

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2. Novel stage gate process regarding product creation, development and engineering process

Sustainable intelligent networking products, collaborative data intelligence, digital twin, sustainable supply chain management SSCM [6,7] and the interlocking of ecological and economics systems bring significant changes with them [8]. Therefore, it is necessary to define a new stage gate process that starts with the project initialization and the idea of a new product and concludes at the end of the project or product life cycle. Multiple layer product engineering models are the state of the art in science and technology. An example for a multiple layer product engineering model is the integrated Product engineering Model (iPeM). iPeM [5] considers customer's demands, offers a transparent platform for information and especially for cross functional communication. The basis for the novel stage gate process is an adapted V-Model and the RFLP PPR-principle.

The adapted V-Model [3] includes the RFLP approach [9] (Requirements, Function, Logic and Physical product) which results in the physical design of a product and uses basic features that are important both for an intelligent product and for the originally intended software development. The RFLP section is used for the solution in the context of product development. The PPR-principle (Product, Process and Resource) is used in the context of production (process) development. RFLP PPR-principle states that data objects are information carriers during the entire product development process and into real production. RFLP and the networked data of product, process and resource are considered holistically. The "P" from the RFLP approach, i.e., the physically designed product, serves as a link to the PPR-principle.

The developed novel stage gate process shows the gates of a new product on the way to market together with applied sustainability and circular economy frameworks. A stage gate process is defined by several process sections. These sections are represented as "stages" and show the development of a new product. Furthermore, gates are strategically defined to review the progress of the project [10].

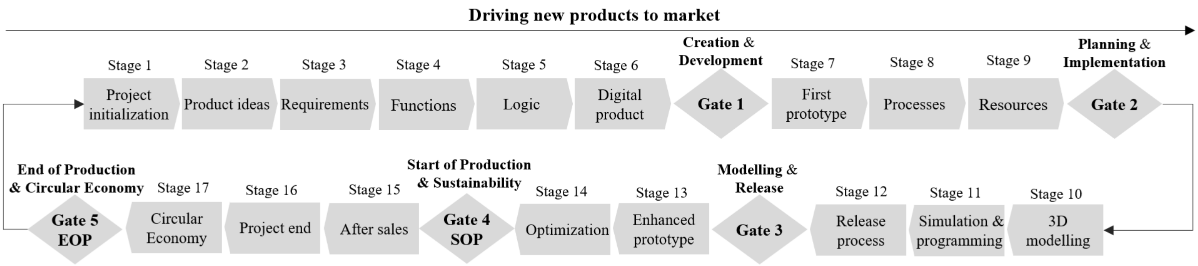

Fig. 1. Novel stage gate process into the product development process.

3. New intelligent networking product considering the concepts of digital twin, sustainability and circular economy

Digital twin includes the characteristics, states and behaviour of an object and is fed by the data that is exchanged between the physical object, the virtual object and the services [11]. The digital twin involves three phases, a digital model, which is the digital representation of an object without any data transfer. The automatic transfer of data from the physical object to its digital representation, which constitutes the digital shadow and the final phase, called digital twin, which represents the automatically integrated data flow between the physical object and its digital representation in both directions [12]. Based on this concept the authors propose the implementation of a digital shadow of a product called Modular Intelligent Mobility Box (MIMB) [13] in order to link product development and production systems. The main user requirement is an intelligent mobile asset that supports daily work or study activities. Simultaneously, the product has to be able to interact with people and environments. Information subtracted during the development process is addressed in the future generations of the product. The MIMB product consists of about 30 modules that can be combined according to certain rules and up to 6 modules can be rented in a service model. In order to ensure data transfer between the individual wireless modules and to enable constant communication with the server regardless of distance, MIMB employs the Long Range Wide Area Network (LoraWAN) technology. The automatic update of data obtained from sensors serves for data analysis and service delivery (digital shadow). Collaborative data intelligence (i.e., user experience, real-time product status...) refers to the value-based processing of the information collected about the MIMB product, providing valuable knowledge for services, desirable or necessary improvements or the development of the next generation of products. As the service provider communicates almost constantly with the customer, the data could even be evaluated in a customer-specific way, resulting in a customised product. In order to offer the customer not only an intelligent but also a sustainable product this approach uses the "cradle to cradle" principle based on the use of biological and technical materials. The development process follows Braungart's vision to revolutionise product development starting with the design, production and use of products and ending with their recycling [14].

4. Future networking product in learning and research factories

The development of the novel stage gate process and its first successful application in the MIMB product define the skills competencies needed by future experts. Furthermore, the specific enablers required to define, understand and implement an intelligent product are defined. The results are structured into feasible learning modules on the base of building blocks. These will be offered in form of face-to-face and virtual lectures, demonstrators, group work and hands-on work in the learning factories. Fig. 2. indicates an exemplary excerpt in form of building blocks concerning the subjects needed for the realisation of new intelligent products with a special focus on sustainability and circular economy issues.

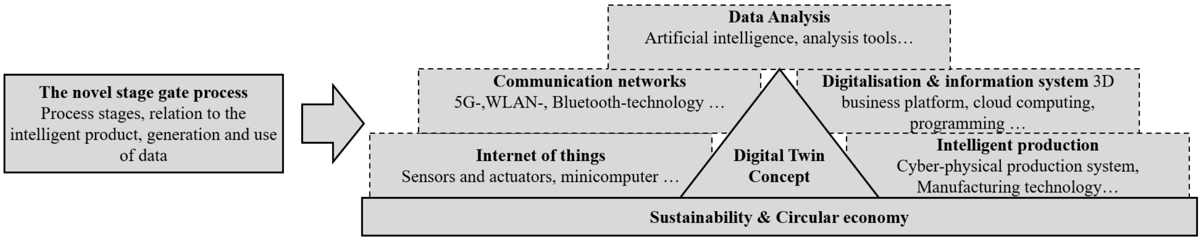

Fig. 2. Learning module to introduce sustainable intelligent products by means of collaborative data intelligence using learning factories.

5. Conclusion

Despite of the importance of using data to develop intelligent products, current literature shows that product development and production systems are not connected and that several product development models do not consider the use of collaborative data. The authors propose a very advanced approach to introduce sustainable intelligent products by means of collaborative data intelligence in the sense of a digital twin with a new stage gate process. Sustainability and circular economy, important factors for future products and productions, have already been integrated for these types of processes. Based on the digital twin concept, the authors introduce the implementation of the digital shadow of an intelligent networked sustainable product model (MIMB), enabling the connection of product development with production systems. During the realisation of this model the advantages and challenges of the development of intelligent products with respect to the use of collaborative data are identified. They define the necessary learning modules for future experts to be trained in learning factories. Thus, this paper presents a new learning module in the form of building blocks comprising theory, demonstrations and hands-on practical parts with modern learning media to introduce future experts to the field of data management and data exploitation. In further work, the implementation of the final maturity phase of the digital twin will be pursued, where products and processes will be optimised semi-automatically or automatically by AI algorithms using data from the product lifecycle, customer feedback, data from other products, etc.

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