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Experiences in Running a Professional Course on Digitally-Enabled Production in Collaboration Between Three Swedish Universities

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Abstract. Needs for new competences and knowledge arise as industry 4.0 evolves in increasingly digitalized production. This development entails that job transformations and future skills need attention from the perspective of industry 5.0, where human and machine find ways of working together to improve production performance. Facing this perspective, one challenge is a growing need for novel lifelong learning initiatives, to meet emerging and altering occupations for the fulfilment of future skill requirements. This challenge is addressed here by portraying a case where three Swedish universities have formed a distinctive collaboration to develop a flexible (i.e. blended) course for professionals, in the subject of Digitally-enabled production. The purpose is to develop a sustainable collaboration between the universities and create a course format on master level addressing lifelong learning for the increasingly digitalized production. The ambition is to increase the impact of the universities respective efforts by sharing resources and utilizing individual specialized expertise to develop a practical and relevant course that can reach a larger target group. The course encompasses industry 4.0 readiness on three levels of production systems; plant-, production cell-, and component level; to adopt a holistic view of digitalization in production. We followed an action research approach for continuously collecting and documenting our experiences during the course development, implementation, and dissemination of the course. Within the frame of action research, an explorative case study describes and analyzes the initiative. The results highlight challenges and opportunities for succeeding with this form of co-produced course. The joint course gives professionals possibilities to work on cases from their own companies with expert supervision from three manufacturing levels to address complex challenges in industry 4.0 implementation. To conclude, the importance of lifelong learning in relation to the human-centric approach of industry 5.0 is emphasized as a future direction.

Keywords. Lifelong learning, industry 4.0, industry 5.0, digital transformation, competence development

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1. Introduction

In the era of Industry 4.0 (I4.0), manufacturing industry is forming strategies for implementation of novel technologies towards increased digitalization [1, 2]. Further, the introduction of Industry 5.0 (I5.0) complements the ongoing era of I4.0 by emphasizing research and innovation to a sustainable, human-centric, and resilient industry [3]. It is argued that companies need to recognize that the next revolution (I5.0) will have an impact on business and management and the collaboration between humans and smart technologies [4]. To meet this foresight, it is important to consider what skills that need to be developed [4] as skilled workers in I5.0 are expected to handle any technological, societal, and managerial issue [5]. Emphasizing this, the need for continuous and effective training to ensure a future skilled workforce is foreseen [5]. This means that new competence and knowledge needs emerge as advanced technologies are embraced in manufacturing and companies becomes increasingly digitalized. We are facing a paradigm shift where companies need to become competitive in digitally-enabled production, this, in turn, is likely to require increased competence development within industry 4.0 [6, 7].

The case reported here stems from a Swedish inter-university collaboration addressing the challenge of meeting industrial competence needs in an era of digital transformation of production systems. Three universities have formed a unique joint initiative to collaborate, bringing their respective in-house expertise [8, 9, 10, 11] on education and research, to co-produce a flexible (i.e. blended) learning course package [12] for competence development of professionals in the subject of digitally-enabled production.

The purpose is to develop a sustainable collaboration between the universities and create a flexible course format on master level to address lifelong learning to improve the readiness for digitalized manufacturing. The ambition is to increase the impact of the universities respective efforts by sharing resources and utilizing individual specialized expertise to develop a practical and relevant course that can reach a larger target group of industrial practitioners, who have been or will be working with digitally-enabled production. The paper explains experiences in running the joint course in terms of the development, implementation, and dissemination process. The paper also highlights challenges and opportunities for succeeding with a sustainable collaboration between the universities around a joint course initiative that meet competence development needs in increasingly digitalized production.

In the following section, an overview of related works focusing on a holistic view of I4.0 for production and the need for lifelong learning, competence development and new skills as part of I5.0 are discussed. Subsequently, the method is described, the case is presented, followed by findings, discussion, and conclusion.

2. Theoretical background

This section describes the manufacturing industry's anticipated technological development within I4.0, followed by illustrating aspects of I5.0 relating to the increased need for life-long learning and competence development in these areas.

2.1. A holistic view of Industry 4.0 in manufacturing

The collected term of I4.0 technologies is herein automation, artificial intelligence, the Internet of Things, and other advanced technologies practiced in contemporary manufacturing industry [13]. I4.0 has the potential of advancing manufacturing into novel ways of e.g., innovation capability, system diagnosis, high productivity, improved flexibility and real time and knowledge-based decision making [14]. However, the process of moving forward with new technologies is challenging [2] and there are many obstacles to digital transformation [15]. The implementation of digital transformation needs to support business model transformation impacting the whole organization [16]. Thus, inflicting major changes in the ways of working emphasize collaboration and considerable interaction [15]. Further, key challenges when introducing innovative technologies have been identified as; poor data strategy and readiness, lack of standardization practices for change, competence and culture gaps, and ad-hoc problem solving [9]. For achieving a holistic view of transformation in digitalization the importance of taking a giraffe view, as opposed to a helicopter view, is highlighted to encompass the entire picture [9]. The giraffe view in this sense means a view from above yet keeping your feet on the ground. All levels at the manufacturing companies need to get involved in and understand the requirements for successful technological implementation, e.g., [17] highlight the importance of management engagement for implementing new digital technologies. A study of the Swedish manufacturing industry showed that as the number of I4.0 technology implementations grows, cooperation and social factors become more essential, in turn leading management to become more distributed and less interested in traditional hierarchical positions [18]. Another related area where a holistic view is emphasized as vital is strategic resilience, to be able to lead to organizational sustainability [19]. It is argued that the process of digital transformation needs to manage structural changes and organizational barriers to progress [20].

To take into consideration the importance of a holistic perspective of digital transformation [21] it should be recognized that different levels in a manufacturing company needs to be regarded simultaneously or systematically when moving forward with technological advances in the era of I4.0.

2.2. Lifelong learning, competence needs and new skills in the eras of I4.0 and I5.0

The manufacturing industry is forming strategies for increased digitization, applying technologies within I4.0. It is acknowledged that one of the challenges with rapid technological changes is the strategic and continuous upgrading of core competences of practitioners [22]. Therefore, one of the largest challenges in this transformation is the lack of competence and skills, and lack of relevant education and training to meet these demands of learning new knowledge [23]. Hence, there is a continuous and growing need for increased and diverse competence development for current and future production personnel [24, 25]. I5.0 complements the ongoing I4.0 advancement by addressing the evolving skills and training needs of employees, e.g., up-skilling and re-skilling particularly digital skills among employees [7]. Emphasizing that there is the recognition of the importance of human interaction and critical thinking leading I4.0 into I5.0 [26]. Digital transformation is challenging and multifaceted and among the key aspects are the importance of skills and digital education [27].

The need and possibility for academia to become a supplier of knowledge to the industry, especially in the era of I4.0, is addressed by [28]. However, traditional

university education is not designed with the purpose of targeting industrial course participants [29]. It has been explained that studies often focus on *what* universities do as partners in workforce development, rather than providing an understanding of *how* universities engage in professionals' competence development [30]. This emphasize that there is a need for novel educational formats on how to design education for competence development. The target group of professionals are working full time, meaning they need to combine employment with part time studies. Hence, there is a balance between running the courses at a pace that enable the time required for the participants to carry out the course and at the same time not being too scattered over time, as dropout rates may increase [31]. With this said, online courses can provide increased flexibility in course implementation with the potential of reaching a more diverse study group [32] Chang [33] proposes interactive learning meaning focus on integrated e-learning and face-to-face learning, entailing that this ensures the process of learning and stimulate learners' interest. Hence, effective and forward-looking manner of managing technological advances in the education sector today is a necessity to ensure sustainability of that sector in the future [34]. Blended course initiatives have proven successful for the target group of industrial participants, for example [8] suggest a collaborative competence e-learning model developed between university and industry. However, such initiatives do not always meet the holistic view of technological advancement in manufacturing, but rather focus on specific technologies in separate courses [17]. Thus, the initiative of collaboration between universities to jointly address the competence need in industry can be a valuable addition to higher education curricula and offering an encompassing course content strengthening the holistic view.

We conclude that for successful digitalization through the aid of I4.0 technologies, it is necessary to take a holistic view of the I4.0 implementation in manufacturing. Therefore, the context of I4.0 coupled with I5.0 may benefit professionals' competence development to be able to learn and work with new technologies holistically across several manufacturing levels.

3. Method

The research in this paper can be described in the context of action research (AR), meaning that the initiative *"is driven by a desire to bring about change in practice and it strives toward a form of action in order to identify and solve problems"* [35]. Action research as a method bridges the gap between academic research and practical work [35]. The work in this paper has run a full cycle within action research, including the common cyclical process with the steps of planning, acting, observing, and reflecting [36]. Within the frame of action research, we consider the course as a case to explore to provide a frame of analysis and reflection. The case focuses on three universities distinctive initiative for a joint collaboration to develop a blended course for professionals within digitally-enabled production. Case studies can be exploratory and are suitable when more in-depth knowledge concerning an event is sought-after [35]. To study the aspects of designing a joint course between three universities the case study methodology was applied to investigate, understand, and describe the context with related implications, in accordance with [37]. The case has elements of design research as the purpose is to develop a novel product (a course), from a need (competence development) to realize the product and fulfil the perceived needs of the stakeholders (course participants and company networks) [38]. During the run of the course, professional course participants

and teachers have continuously discussed the course content and format to identify industry knowledge needs and accordingly mutually harmonize course content and format, aspects as stressed by [39].

4. The KIT course case

The case focuses on the collaboration between three Swedish universities and their respective company networks to co-produce a course at the master level, targeting competence development of industrial professionals. The research takes place within the context of the project "Competence needs and courses for professionals in IT and competitive production". The KIT project is an inter-university educational project financed by Vinnova, Sweden's innovation agency. The purpose of KIT is to meet the manufacturing industry's competence needs, through customized higher education courses at master level. The three participating universities, namely Mälardalen University (here after referred to as MDU), University West (here after referred to as UW), and Linneaus University (here after referred to as LNU) have long traditions of close collaboration with industry, via research and education in specialized competence areas as well as laboratory infrastructure related to Industry 4.0 and smart production, where approaches for meeting manufacturing industry competence needs have evolved over time [8, 40, 41]. The three universities also have a supportive co-production platform with the surrounding society, through which they have a continuous dialogue and assessment of competence needs. Their respective understanding of the manufacturing industry's specific competence needs is applied jointly to develop a suitable course curriculum for professionals working full time. Figure 1 illustrates the multi-way collaborative opportunities.

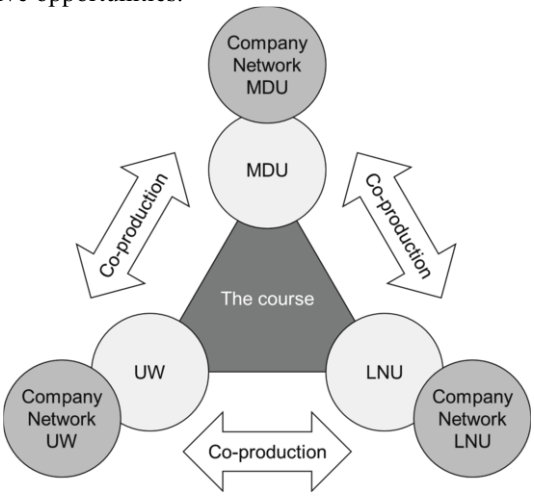

Figure 1. Multi-way collaborative opportunities.

The specific course is of 7.5 ECTS credits within digitally-enabled production, jointly designed by three Swedish universities. The course aims to support and facilitate our partner manufacturing companies to become competitive in digitally-enabled production. The course content addresses the prerequisites and capabilities required for implementing I4.0 technologies in the context of an overall production system. More

specifically, the competence base of companies in three areas are focused: internal logistics, virtual factory, and sensor and signal processing. These three areas holistically interconnect the key components for the successful implementation of I4.0 in manufacturing. Each university develops a course module of 2.5 ECTS, addressing the area related to their specialist competence. Table 1 gives an overview of the content of the course and its three modules.

Table 1. Overview of the content and modules of the course Digitally-enabled Production, 7.5 ECTS.

Digitally-enabled Production, 7.5 ECTS (part time course with 33% study pace) The course covers the holistic perspective of I4.0 implementation. It includes overall plant level, production cell level, component level, and outlines how to interconnect them in an efficient way. It enables the possibility for industrial professionals to work on real industrial cases from their own companies with the expert supervision from three universities, complementary to address the complex challenges in I4.0. The course supports theory in symbiosis with practical laboratory experiments, onsite seminars and web seminars. Further, the course facilitates access to several larger industrial companies' network and the possibility to exchange ideas and experiences within these networks.		
Course module 1 Internal Logistics in Industry 4.0, 2.5 ECTS MDU	**Course module 2** Virtual Factory and Robot Cell Simulation, 2.5 ECTS UW	**Course module 3** Data Acquisition and Monitoring, 2.5 ECTS LNU
- The internal logistics system and its structure - Efficiency and performance improvements in internal logistics - Relevant technologies within I4.0 and their potentials and challenges for internal logistics - Design of internal logistics systems 4.0	- Virtual factory and digital twin including factory scanning - Theoretical and practical study of robot simulation for decision making and factory solutions - Simulation and programming of industrial robots using commercial robotic simulation tools	- Sensors and its principles for measuring acceleration and strain - Analogue-to-digital converters and data acquisition - Robust fundamental signal processing methods for I4.0

Figure 2 shows the course structure with the three course modules across the time frame. The different shaded grey colors in Figure 2 demonstrate that all universities were involved in design and coordination of each other's modules.

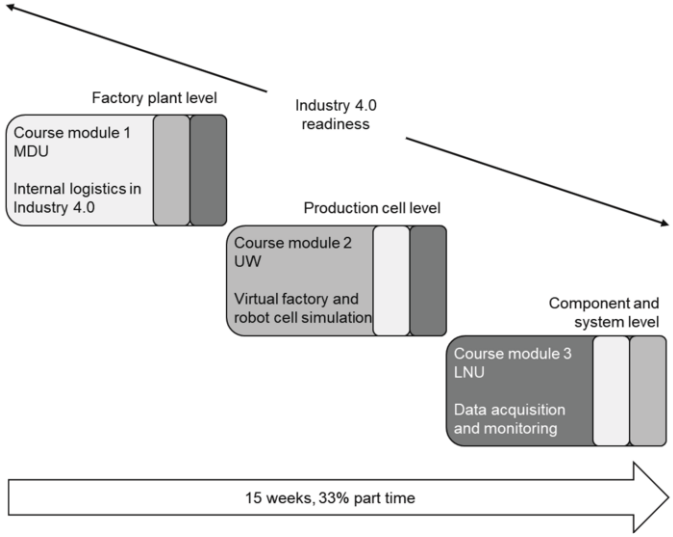

Figure 2. Course structure with three course modules over time.

The course was first given during the autumn term of 2020, during a period where Covid-19 restrictions in Sweden varied and changed throughout the running of the course. This meant that some physical labs took place, and some of the planned physical activities were changed into an online or hybrid format. This first running of the course went through all four action research cycles of planning, acting, observing, and reflecting.

The expected job roles of professionals taking the course were in the areas of: manufacturing engineering, logistics, automation, robotics, maintenance, and quality, as well as production management. Professional course participants should complete assignments for each course module to move to the next module, where the completed assignment from one module provided input to the next one, enabling the participants to encompass a holistic view of the industry 4.0 readiness in their production system.

5. Findings and Discussion

This paper concentrates the focus towards the course design and the collaboration between the three universities. This means that the primary focus of this paper has been on joint course design issues, rather than analyzing the course from the course participants' point of view. Through the action research approach, we have explored the course design as a case to identify and reflect on potential opportunities and challenges within the course. We focused on three phases of the inter-university collaboration to design a joint course i.e., development, implementation, and dissemination, as indicated in Tables 2 and 3. The development phase focused on planning and preparing course plans and content. The implementation phase focused on experiences from running the course. Finally, the dissemination phase considered aspects of how the course can become a long-term sustainable course and included among regularly advertised course curriculums. Drawing from the key opportunities and challenges, we thereafter summarized improvements made for future courses and described our recommendations for successful inter-university collaboration for jointly running courses for competence development for professionals.

5.1. Key opportunities and challenges in course development, implementation, and dissemination

There are several opportunities when embarking on a journey towards a joint inter-university course for professionals' competence development, as outlined in Table 2. The flexible course mode can be attractive for professionals and makes the inter-university collaboration feasible. The combination of respective university's expertise mean that the manufacturing competence needs can be met holistically, encompassing several important levels in production plant's shop floors levels. The course participants brought in real industrial cases and have worked on them throughout the course, which is a main course pedagogical approach, closer to the problem-based learning and activity-based learning. The pedagogy throughout the course on including real cases emphasis this further. The knowledge exchange between university lecturers encourages up-skilling through auscultation. Further, the initiative it opens up for future inter-university collaborations, such as joint research ventures.

Table 2. Key opportunities for course development, implementation, and dissemination.

Key opportunities	Description of opportunities
Providing a holistic course, during planning and implementation	By combining lecturers from different areas of expertise, the course can better meet the manufacturing industry's competence needs, especially the aspect of holistic implementation of I4.0 in production.
Attracting diverse participants, during implementation	By co-producing a course, each university were introduced to participants in the collaborating universities' company networks, thus attracting participants that normally not apply to its courses. The flexibility of the course mode appeal to professionals, despite geographical belonging.
Knowledge exchange between participants, during implementation	Course participants were encouraged to bring real cases from their work environments into the classroom and relate those to the theory of the course content. In combination with the diversity of the participants, it enabled the participants to gain knowledge about companies outside their own geographical region
Knowledge exchange between lecturers, during implementation and dissemination	The lecturers, from the three different universities, engaged in the course provided different views of implementation of I4.0 in production. Further, they may be introduced to new forms of teaching (e.g., through auscultation). This knowledge exchange can facilitate competence development and more skilled lecturers.
Extended collaboration, during dissemination	Joint courses between different academic partners open up opportunities for collaborations in other areas, such as student thesis work and prospects for joint research projects.

Despite realizing many key opportunities with the joint inter-university collaboration for courses for professionals, we also experienced several key challenges, which needs to be addressed to succeed with this joint initiative, see Table 3. The course format needs to be adjusted to suit professionals working full time and it is crucial to coordinate the course activities between the three universities in a smooth way. For example, each university has different formats for course plans, which of course had to be mutually agreed upon to design a course together. Additionally, several attempts were made to engage the respective communication departments at the three universities in the promotion of the new course. However, it was proven difficult to engage them, to organize joint meetings, and to get across the message of marketing towards a new target group of professionals.

To gain holistic knowledge of I4.0 implementation related to different manufacturing levels, we envisioned that the professionals should take the course as one unit. However, legal restrictions meant that the professionals had to be admitted separately to each module (at different universities), i.e., contradicting the ambition of emphasizing the holistic approach. The course ran part time during autumn of 2020. This eventually extended the course time. Moreover, the universities did not have the same type of Learning Management Systems (LMSs). This caused extra administration for lectures and confusion among course participants. Finally, an overall demanding challenge is how to achieve a long-term sustainable joint course that is included among the universities regularly advertised course curriculum.

Table 3. Key challenges for course development, implementation, and dissemination.

Key challenges	Description of challenges
Different types and processes for course plans, during planning	The design and administration of course plans differed between universities, e.g., writings of describing requirements for admission had to be negotiated to reach consensus.
Joint promotion, during planning and implementation	It was proven difficult to engage the communications departments from respective university and to commonly market the new course to the target group of professionals.
Admissions to the course, during implementation	The idea is that the course is to be read as a unified course, including several aspects of I4.0 implementation related to different manufacturing levels. This for professionals to gain holistic knowledge of the subject area. Though, due to legal restrictions, participants needed to be admitted to each module separately.
Disparate learning management systems, during implementation	Different LMSs caused extra administration and confusion among participants and universities.
Long-term sustainability, during dissemination	The course was developed as a pilot course, and it is not obvious how to sustainable include it among regularly advertised course curriculums at each university.

5.2 Improvements and recommendations for inter-university collaboration for a joint course design

After having encountered both key opportunities and challenges when following through a full cycle of development, implementation, and dissemination of the joint course, we summarize our experiences in improvements to be made for further courses, as well as recommendations for inter-university collaboration for successful course design.

- Realize that co-producing a course through inter-university collaboration requires more time for both planning and running the course. Coordination on distance and among disparate systems and formats mean that a greater number of activities are needed, which ask for more allocated time.
- Create opportunities for close collaboration between the university partners early in the development process, both through online activities, but also to set off time for physical meetings for improved understanding, synergizing competences and the content, and continuous problem solving.
- Distribute the course material in a concise and clear manner to the course participants. This was proved difficult in the explored case as the universities used different LMSs and were not, due to restrictions, able to access and add content to each other's LMSs. In preparation of the next course, it has been decided to use Teams as a common LMS. This should also work well for professionals from companies as it is a commonly used tool in the industry.
- Joint advertisement of the course proved difficult and trying to unite the universities respective communication departments failed despite several attempts. This needs to be distinctively addressed in future course ventures to understand what is necessary for achieving greater engagement from those functions at the universities and to understand and device how communication departments can collaborate across university boarders.
- Inform, engage, and collaborate closely with support functions e.g., course administration and admissions office early in the development process. This is

necessary to ensure their understanding of and create a realistic plan for implementation of a new course initiative. It is important to address this early, especially if the course do not follow the regular academic time plan.

- Finding an efficient and clear way of admission procedure that supports inter-university collaboration is necessary to avoid the multiple application processes to three separate universities.
- Applying a blended course mode proved to be a strength, it appealed to the professionals as a flexible format, but also being partly planned online from the start meant that the move to fully online format due to Covid-19 was less stressful. Also, for future courses, it is recommended to communicate with partner companies to choose specific days and times that may best suit professional's work.

The case outlined gives an unusual encompassing view of aiming for meeting manufacturing industry competence need on several levels i.e., plant, process, and sensor. However, a specific area that can be improved as regards to the course content and the ambition of giving a holistic view of the I4.0 implementation in production could be the incorporation of aspects related to the strategic management around I4.0. This should be considered for future courses. Finally, and perhaps most importantly we ask; how the course can become long-term sustainable and included among regularly advertised course curriculum? The outlined case shows many opportunities and recommendations for meeting the challenges. Thus, a prolonged collaboration can be envisioned as rewarding for both collaborating universities and partaking company professionals. Nevertheless, the initiative requires resources and needs continuous nourishment to grow and thrive for the inter-university collaboration to be continued.

6. Conclusion

The purpose was to develop a sustainable collaboration between universities and create a flexible course format on master level to address lifelong learning to improve the readiness for digitalized manufacturing. The three collaborating universities combined their expertise across manufacturing shop floor levels to create a course that takes a holistic view of implementing I4.0 in production. It is recognized that manufacturing industry needs competence development in I4.0 and in the wake of the human-centric era of I5.0. In this context, one of the challenges is the continuous and growing need for novel and innovative initiatives to promote lifelong learning, to meet emerging and altering occupations for the fulfilment of future skill requirements. Thus, learning trajectories and training paths in the manufacturing industry may change or may need adjustment, for which new models of lifelong learning are required. This paper highlights the need for competence development in the era of I4.0 that encompasses the plant-, production cell-, and component level in a manufacturing company. The paper explains experiences in running a joint course in digitally-enabled production and emphaise opportunities and challenges in the planning, implementation and dissemination phases. Improvements and recommendations for future inter-university collaborations in joint courses are outlined. Throughout the progression of the initiative the industrial course participants, i.e., the practitioners, were involved jointly with the academics in co-producing the course. E.g., co-production took place when selecting real cases for project work, and a focus group with participants at the end of the course, reviewed and reflected

the course format and the industrial applicability of the content. Such activities strengthened the AR approach bringing in practitioners' valuable knowledge [35].

The case study demonstrates the course initiative, targeting the understanding of design of flexible and blended learning aiming for competence development of professionals that are studying in parallel with full time work. The blended course format was adapted to different workplace situations and was quickly revised to meet restrictions during the Covid-19 pandemic. The joint course venture gives possibilities for industrial professionals to work on real industrial cases from their own companies with the expert supervision from three universities to address the complex challenges in I4.0 implementation in production, and to highlight the perspective of I5.0. The course initiative emphasizes the importance of taking a holistic view of I4.0 implementation in production and involving several manufacturing shop floor levels. In relation to this, human interaction, and critical thinking, i.e., aspects of I5.0, highlight the necessity of life-long learning and novel initiatives for competence development of professionals where the human-centric approach of I5.0 is emphasized as a future direction.

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