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Lasse Christiansen [1,2,*,†], Tommy Edvardsen Hvidsten [3,†], Jesper Hemdrup Kristensen [2,†], Jonas Gebhardt [4], Kashif Mahmood [5], Tauno Otto [5], Astrid Heidemann Lassen [2], Thomas Ditlev Brunoe [2], Casper Schou [2] and Esben Skov Laursen [1,†]

1 Design and Production, University College Northern Denmark, 9220 Aalborg, Denmark
2 Materials and Production, Aalborg University, 9220 Aalborg, Denmark
3 Fagskolen Viken, 3616 Kongsberg, Norway
4 Institute of Vocational Education, University of Flensburg, 24943 Flensburg, Germany
5 Department of Mechanical and Industrial Engineering, Tallinn University of Technology, 19086 Tallinn, Estonia
* Correspondence: lc@mp.aau.dk
† These authors contributed equally to this work.

Abstract: The advent of Industry 4.0 is changing the role of human labour towards a more supportive function in the production system, requiring new digital-, technical-, interdisciplinary-, collaborative- and communicative competencies. This challenges educational institutions to develop new teaching activities and materials to address ever emerging needs. To address this, this paper presents an Educational Framework to support educators in developing new teaching activities and study material for Industry 4.0. The model distinguishes itself from other educational design models by combining an iterative approach toward problem-solving, with the concept of authentic task design, as the core elements. Based on 14 pilot cases, it is concluded that educational framework have increased the educational activities in the areas in focus.

Keywords: educational design; process model; capabilities; Labour 4.0; teaching

1. Introduction

Information and communication technologies have led to new industry opportunities [1–3], often referred to as the fourth industrial revolution or, in short Industry 4.0. The core concept of Industry 4.0 can be described as machines and products autonomously exchanging information, self-configuring and self-organising, leading to flexible, modular, intelligent, and cyber-physical production environments [1]. This transformation towards smart machinery and new capabilities also set new requirements for work tasks, operators and technicians [4,5].

As a result, the role of human labour in the manufacturing industry is also changing. Human labour is changing towards a more supportive role in the production system rather than directly involved in the production processes, e.g., assembling the products [6–8]. Consequently, employees need new technical-, interdisciplinary-, collaborative- and communicative competencies [6,8]. Traditionally, many educational programs within the technical fields have focused almost exclusively on developing technical skills and much less on social and interpersonal skills [9,10], which is found to be a requirement for Industry 4.0 and is supported by recent studies [11] and reports from the world economic forum [12]. To address the new role of human labour, educational institutions within the technical fields must develop new teaching activities and materials. However, the needs, teaching method and approach for making these changes are unclear, as Industry 4.0 is a broad, alternating, and complex area. Hence, there is a need to support the educators in handling the complexity and uncertainty [13].

Since Japan launched its fifth science and technology basic plan in 2016, the term Society 5.0 has emerged as a way of complementing the societal aspects of the Industry 4.0 era, aiming for a prosperous human-centric society [14]. EU's initiative "Industry 5.0" rests upon the Society 5.0 objectives and values, however pointing out the industry's role in the transition. Our understanding is that Industry 5.0 is based on the Industry 4.0 technologies and address the societal and organizational consequences of the Industry 4.0 paradigm as well as needs stemming from sustainability issues and the society through political objectives [15]. Our question is what will the consequences for the learning of professions be as the society moves towards the Society 5.0 "super smart society" [14,16].

The research into this issue is still somewhat meagre, but there are a few aspects that have bearing upon our project. Ref. [17] points out several characteristics of Society 5.0 learning needs: students' ability to think critically, deductively, and inductively. They also state that students must learn faster and to a high extent through practical experience and underline the need for social competences and a high degree of reflexivity. This supports the claim for Industry 4.0 learning needs, and enhance the need for social skills, reflexivity and experiential learning [18,19].

Approaches to these challenges have been identified on the institutional level [13], identification of needed skills [10], and with a focus on learning mechanisms [20]. However, all of these approaches are descriptive in the sense that they describe the optimal learning setting, yet remain unclear on prescribing a path towards it. Several descriptive approaches to teaching the skills required for Industry 4.0 has been presented, most notably the learning factory [21,22] and teaching factory [23,24] approaches. However, Enke et al. criticises these models for their technology-centric approach [25], where the didactic dimension has been underdeveloped compared to mature technical and operational models. Hence, the learning design for technical education still needs improvement.

Traditionally, learning activities have been developed by the educator, by various models, e.g., SMTTE [26] or the Relational model [27]. Newer approaches involve co-creation, which can be used to create a design for the learning activity [28]. However, a prescriptive approach for educators on how to develop learning activities targeting Industry 4.0 does still call for new approaches, due to the complexity and changing requirements within the field.

This research aims to propose an educational framework that educators can use to guide educators in designing learning and teaching materials for a complex and changing environment while considering the didactic challenges. To define the framework, this article answers the following research question: *What should an educational framework address to make it relevant for Industry 4.0, and how can such a framework contribute to better educational targeting of Industry 4.0?*

The article describes the relationship between industrial development and the corresponding learning processes within technical training and education. This is followed by a conceptual discussion of how the current situation of Industry 4.0 affects education. Based on this, the Educational Framework is developed. This is followed by an empirical test of the framework, including a discussion on its contribution and further research.

2. The Development of Learning Processes towards Industry 4.0

Industrial development has historically significantly affected educational programmes' shape, content, pedagogics and didactics [22]. The most notable success criteria for educational programmes is whether graduates from such programmes will be able to fulfil the future needs in the labour market, hence providing the basis for continued growth and prosperity of the society. Understanding the development of needs in the labour market is an essential guide for creating new approaches and methods for developing teaching material and activities [23].

Historically, the Swedish scholar Lennart Nilsson studied the Swedish public system for vocational education and training (VET) through a comprehensive examination of public documents directing and describing the sector [29,30]. The time scope of the study

was from the end of the guild-based education in 1846 to 1980. The study resulted in many interesting findings, including the strong relationship between the organisation and activities in vocational schools and the industry they supported. Based on their findings, Nilsson identified the following defining dimensions to describe the relation:

1. Planning of work (learning "unit" and training direction). Nilsson found that the working tasks were the core element for planning in the industry and that this was the fact in VET. When the industry moved from the craft-based paradigm of the industrial revolution to mass production, the planning focus moved from a holistic view of the tasks to a method-centric view; how can the tasks be divided and arranged to achieve the highest productivity? This was the case in VET as well. A system was established where the students moved from workstation to workstation, studying divided and adapted tasks. One station focused on the clutch in the car mechanic training, and the next was the differential. The system is still very much alive; the lab equipment suppliers for VET still deliver ready-made "learning stations" with adapted artificial learning tasks for any VET sector.

2. The organisational structure. Nilsson found that how school learning activities were organised mimicked the organisational structure of the work in the industry. The prevailing industrial paradigm following the second world war was scientific management, as described by Frederic Taylor. This was also the model for the Training Within Industry (TWI) system that was highly successful as workplace-based training during WW2. Nilsson found that the Swedish VET was highly influenced by this system and organised their activities by individual learning stations self-contained with tools, materials, and manuals in an assembly line fashion.

3. Character of the tasks. The adaption of the working (learning) tasks in industry and VET is also closely connected. When the industry transformed from the craft-based paradigm to the fordistic era, the tasks moved from holistic tasks to create value for the customer to a divided instrumental task designed to fit into the worker's spot on the assembly line. In VET the tasks moved to mock-up tasks designed to learn a small part of a whole system.

4. Work mode. This describes whether the working/learning tasks are solved individually or as a team. In the craft-inspired industrial era, a team working mode was prevalent; when the station-based model of the mass-production era entered the VET workshops, the individual mode gained ground as the students rotated between the stations.

5. Nature of communication. This feature describes the characteristics for communication of work/task-related communication in the work/learning space. With the introduction of the learning stations, the communication moved from oral communication between the manager/teacher to written instructions. The TWI system had a system for conveying the needed information based on structured lists of "steps" and "key points", a more instrumental way of communication. You can find the reminiscence of this in today's eLearning provision.

If we accept the significance of the relation between the industrial paradigm and the educational mode in vocational and professional training according to Nilsson and along the dimensions he proposed, we may deduct characterising features of learning activities, objectives, and outcomes for Industry 4.0.

The basic planning unit is the task of manufacturing highly customised products. In training, this translates to a holistic relation to the finalised authentic products and the system(s) needed to manufacture them. Thus, the learning tasks are to create a final product, not tasks adapted for learning a reduced part of a divided learning outcome. The task is also situated in an authentic context of manufacturing systems and machines, such as one can find in the learning factories, which recently have experienced increased popularity [22]. However, authentic can also be understood in a broader sense, as a problem with a real-world context [31], which allows the learner to relate the new knowledge to their existing knowledge [32].

The organisational structure is characterised by highly integrated, flexible, autonomous and automated production facilities, where the machines and systems communicate both independently of humans and with humans. Due to the high flexibility, Industry 4.0 opens for a cost-effective production of small, customised manufacturing runs, while virtual testing and simulations aid the transition from one product (variant) to another. Some of the tasks are performed in virtual workspaces complementing the physical processes. Humans perform tasks where human capabilities are needed and aid the machines' operations [33].

The structure requires a holistic approach to the complete value chain of the operation, which demands interdisciplinary oversight and competence from the workers and professionals in the manufacturing industry. The work mode is task-oriented, highly autonomous and conducted in inter-disciplinary teams and/or networks covering all domains needed to solve the tasks. Summarily, a new educational design tool needs to address the three following areas:

- An offset in context, which ensures industrial authenticity.
- A task-based learning approach that enables multidisciplinary group work.
- A design-inspired approach toward problem-solving, where understanding the context and applying an iterative process are key elements.

3. Methods

The research has been conducted as an engaged scholarship [34,35], adding to the quality of higher technical education, as well as providing new knowledge within technical education. To achieve this, a three-step approach was applied. This can also be seen graphically in Figure 1.

1. Background analysis of industrial needs: A background analysis, enquiring industrial stakeholders about the current and future skill requirements for working with Industry 4.0. In total, 94 stakeholders gave their input, rooted in the industrial needs and matching educational capabilities.
2. Development of educational framework and training concept: A theoretical foundation, the educational framework, and the training concept for educators was developed based on the input from the first analysis. It was developed among the project partners following an iterative approach. The elements of Table 1 and the industrial analysis were considered together with the theory presented in this paper.
3. Educational pilots for framework testing: The educators evaluated the educational framework through 14 educational pilots, in five European countries, with a total of 450 students. They developed a new educational activity of 5–30 ECTS points (course to full semester), targeting EQF levels 5–7 (higher education), with industry 4.0 scope.
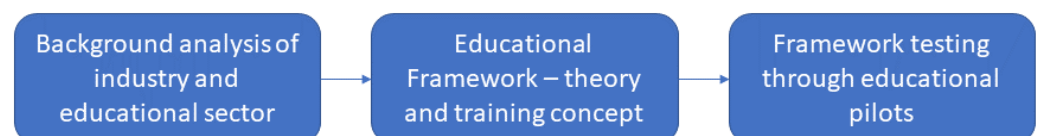

Figure 1. Flow of the applied three-step method.

Table 1. An overview of which characteristics education and instruction had during the four industrial paradigms.

Characteristics	1st Industrial Paradigm [29]	2nd Industrial Paradigm [29]	3rd Industrial Paradigm [29]	4th Industrial Paradigm (Proposed)
Orientation of production	Placework and small production runs	Large production runs	Functional parts of large and small production runs	Customised small production runs
Processing (work techniques)	Dominated by manual techniques	Dominated by mechanical techniques	Computer techniques and electronics combined with mechanical and manual techniques.	Highly flexible and interconnected automated production technologies, occasionally working in close interaction with humans.
Planning of work	Task-oriented	Method-oriented	Task-oriented with focus on job rotation and job enrichment	Dynamic and adaptable authentic tasks, physical and virtual. Plan verification through simulation on real-world data or digital twins.
Work mode	Group-oriented	Individual	Group-oriented and combined with individual work	Group-oriented
Organisational structure	A craft-oriented organisation similar to that of apprentices, journeymen and master working	Dominated by the individual working on the specific task allocated to them	Dominated by a group working with functionally coordinated pieces of work in partly self-controlled groups	Highly autonomous task-motivated groups, based on inter-disciplinary competence from multi-disciplinary networks, aided by non-human agents
Character of the tasks	Mainly dominated by authentic tasks	Mainly dominated by synthetic tasks	Functionally coordinated authentic tasks	Authentic physical or virtual tasks
Nature of communication	To a large extent personal communication and concrete illustrations	To a large extent indirect communication in the form of written instructions and written illustrations	Personal and indirect communication	Personal and indirect communication augmented by technology according to subject.
Advantages	Deep process understanding	Fast and Simple	Better relation between training and work, better learning outcome, and decreased dropout	Integrated training, work mode and learning outcome according to current industrial needs.
Challenges	Hard to scale	Low relation between training and work, reduced learning outcome, and increased dropout	Hard to target complex processes, and tedious adaption of cases and tasks	Instrumental virtual training might increase dropouts and affect learning outcome quality

These three activities were evaluated in correspondence with the Framework for Evaluation in Design Science Research for research evaluation [36], which describes that problems with high human factors should be evaluated formatively in a natural environment after a few artificial tests:

1. The background analysis was performed partly from the literature and partly from interviews with stakeholders. All partnering institutions surveyed 10+ relevant stakeholders from their countries. It is reported in a separate publication [11].
2. The concept was evaluated formatively by educators from six higher education institutions. This increased quality and was a test in a more naturalistic environ-

ment. The training material is published at https://fagskolene.online/courses/teffic-pedagogical-framework-for-industry-4-0/?lang=en (accessed on 21 September 2022).

3. The educators who conducted the 14 pilots performed both summative (learning outcome) and formative (reactions to the course) evaluations of the courses [36]. This was done as a combination between the institution's existing evaluation procedures and course-specific activities composed of the educators. After the course, the gains and challenges were reported to the Transforming Educational programs For Future Industry 4.0 Capabilities (TEFFIC) project management. The compiled evaluation can be found at www.teffic.eu or https://www.ucviden.dk/da/projects/transforming-educational-programmes-for-future-industry-40-capabi (accessed on 21 September 2022).

The evaluations was carried out at the individual institutions according to their quality insurance guidelines. At all institutions, this included both questioner data as well as open-ended evaluation at the end of the courses. These evaluations were collected by the educators conducting the educational activities, and processed into an evaluation collecting the learning goals, a learning activity description, and the positive and negative quantitative data as well as any qualitative assessments from the local quality insurance system.

To investigate whether the proposed educational framework meets the demands presented in Table 1, the collected evaluations among educators and students are analysed regarding the four Kirkpatrick levels: reactions, learning, transfer, and performance. Trends that do not fall within these four categories will be described [37]. This analysis was conducted as a Gioia analysis, where the qualitative results from the evaluations was grouped first based on the words used by the individual evaluators, and afterwards towards the four Kirkatrick levels [38].

4. The Educational Framework

As described, both the focus on context and tasks and the agility of the design process are vital elements of an educational framework for Industry 4.0. Hence, the framework development presented in this paper started with a focus on these three elements.

Nilsson [29,30,39] argued that professional and vocational skills and competence are consequences of the human's task-related professions. It implies that the tasks dictate the obtained competencies [29,30,39]. This realisation is at the core of the Educational Framework. One of their major discoveries was that reducing the tasks according to the training within industry principles led to decreased learning outcomes and dropout from the study programmes. These findings support the application of authentic holistic tasks at the core of the learning process. This strategy is supported by contemporary research [40,41]. Merrill [42] later developed an instructional theory named 'First principles of instruction', which give explicit guidance on ensuring a higher learning outcome, taking a point of departure in a task-centred approach. A prominent feature of Merrill's theory is that it places the task as the central element in the learning process. It resonates well with Nilsson's work, as he argued that the task is imperative, developing teaching activities and material. Accordingly, a learning process based on the 'First principles of instruction' places the core task at the centre and relates all learning activities. This describes the organisational structure predicted in Table 1, where interdisciplinary groups work on authentic tasks relevant to future employment. Furthermore, the tasks are where the Industry 4.0 context is materialised by using industrial relevant technologies as both case and learning vessel, as described in, e.g., the learning factory literature [22].

The approach embedded in the model is based on agility, as having an agile approach has proven to hold some measurable advantages over traditional educational development methods regarding handling the ambiguous definitions and complexity of the situation [43]. The agile approach allows understanding of the situation to evolve through the process, which is fundamental when the problem at hand is not fully understood from the beginning. This becomes even more relevant when the problem is a dynamic and adaptable authentic

task, as described in Table 1. Hence, the solution and understanding of the problem are co-developed through an iterative process [44].

The model (see Figure 2) aims to combine a holistic approach to developing teaching activities and material (identifying and analysing the needs and boundaries), focusing on the detailed development of the activities/material (the circle). Moreover, the overall agile approach is combined with a task-centred principle, as task-centred models, e.g., authentic task design, have provided significant learning outcomes within technical educational programmes, creating a natural setting [31,45].

The model's core is the iterative approach toward developing the teaching activities, represented as a circle with five steps in the model (Phase 2—see Figure 2). The other two key phases are, (Phase 1), the initial analysis leading to the learning needs and boundaries, and (Phase 3), the execution of the educational activities, including feedback. Below is a short introduction.
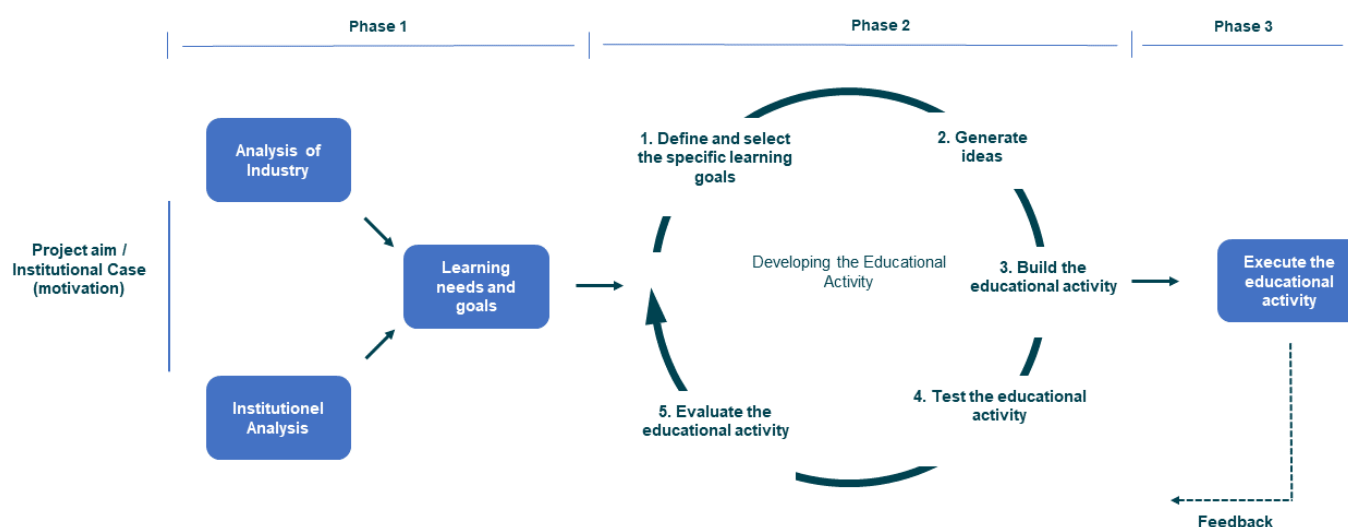

Figure 2. The Educational Framework.

The initial analysis establishes the learning needs and boundaries. Based on the results of the analysis, activities and materials are developed. Afterwards, the educator executes the activities in collaboration with the students. Finally, the activities and materials developed are evaluated by both the educator, student, and potentially also peers.

4.1. Phase 1

An analysis is conducted to identify any gap between industry needs and educational capabilities to ensure that the general learning goals are supported by practice. The analysis results in a set of learning needs, boundaries and opportunities within the higher education organisation. This initial analysis can serve as the foundation for several educational activities related to an educational programme. The analysis should not be conducted before developing an educational activity but should be updated regularly to ensure its relevance. The analysis framework must be adjusted to the specific situation, educational program, and educational organisation(s). However, the one used in TEFFIC (The Erasmus+ project co-funding the development of the Educational Framework) can be used as inspiration for developing a focused framework [11].

Phase 1 result in a set of learning needs and goals, combined with the institutional capabilities, which are the boundaries for meaningful educational activities targeting the industry.

4.2. Phase 2

The iterative development of education consists of five steps, see Figure 1. In the following, the process of each of the underlying steps is described in greater detail.

1.　　Define and Select the Specific Learning Goals;
2.　　Generate Ideas;
3.　　Build the Educational Activity;
4.　　Test the Educational Activity;
5.　　Evaluate the Proposed Educational Activity.

The educational activity is ready for use if it meets the learning goals. If not, the activity must be redesigned.

The choices regarding educational technologies, infrastructure, and resources must be considered in this phase. The initial mapping of educational capabilities revealed that many institutions had access to learning management systems, augmented and virtual reality devices, learning factory equipment and simulational software [11]. The learning management systems allow for several didactical approaches, such as blended learning and flipped classroom. These, and other locally available learning technologies must be evaluated iteratively, as suggested in this phase, as it finds potential flaws in the learning design.

Phase 2 results in a learning design which can be taken into the education and be executed among the students. This includes both what, when, where and how to learn, and which infrastructure is needed.

4.3. Phase 3

The execution uses the developed educational activity as a plan, which is the overall reality check for the plan. After the program's execution, several types of feedback can be obtained. This feedback targets the execution, the planned activity, the learning goals, the learning needs and the industry. Several methods can be used to obtain feedback, including interviews, questionnaires, and workshops. The educators' reflections are also crucial in this process, as the educators and the students are participating in the educational activity at different premises. The test approach must be adjusted to the specific situation, educational program, and educational organisation(s).

The feedback acquired in phase 3 comes in several forms, and serves purposes in both phase 1 and 2: Feedback towards students' reactions to the course and learning outcome targets in phase 2. If the students find the learning activity to be poorly organised, if learning goals are missed, or if positive outcomes need to be maintained, this is used in the following design cycle.

Phase 1 is influenced by graduates' feedback on using the acquired skills and how these can aid the choice of learning needs and goals. Likewise, feedback from the industry can be added to new industrial and institutional analyses.

5. Learning Activities and Their Characteristics

The 14 developed learning activities, their contents and results can be seen in Table 2. Note that 5 of the educational activities were second iterations of the same educational activity, and hence received feedback from the first iteration.

These learning activities all provided the desired results learning wise, implying that the educational framework is use-able for planning technical higher education.

Table 2. The 14 conducted educational pilots. Two numbers marked pilot with two iterations.

Pilot Number	Pilot Theme	ECTS Count	Pilot Design	Pilot Results
1	Global business performance	5 ECTS	Analysis and optimisation skills trained through flipped classroom and blended learning. The students work in teams on authentic industrial problems	The reactions, as well as the learning outcome, improved compared to previous courses. The learning goals were meet, and in general the students recommended to conduct the course likewise in the future.

Pilot Number	Pilot Theme	ECTS Count	Pilot Design	Pilot Results
2	Product development	5 ECTS	Product development skills trained through flipped classroom and a miniproject in an Industry 4.0 learning factory setting	The learning outcome was more than 75% correct answers in tests. Furthermore, the reduced lecturing time due to the flipped approach allowed for more practice.
3 + 4	Digital manufacturing	6 ECTS	Manufacturing skills learned in an online environment with aid of industrial simulation software for practice and illustration	The students both thrived during the course and obtained their learning goals in both iterations. They had a positive attitude towards the digital tools, were able to relate them to prior knowledge, and inteded to use them in future projects. Furhtermore, they were able to identify several new learning needs related to their new knowledge.
5 + 6	Industrial digitalisation for skilled workers	30 ECTS	This full-semester course targets agile production, internet of things, and industrial intelligence. This was obtained wiht blended learning, learning factory setups and digital simulation tools.	The first iteration showed good results, giving only positive feedback. However, the second iteration showed improved quallity of lectures and compliance between learning needs and outcomes, but lower satisfaction with the process. These inputs lead to further iterations for future course execution.
7 + 8	Megatronica	5 ECTS	The course aims to integrate the prior knowledge of programming, electronics and mechanics. This is done in a blended learning setup with simulations as support in supervised groups.	The students reported both good learning outcomes and reactions to the course. They managed to get the hardware running, and even though the lab-time was reduced drastically (COVID19), all groups still produced well-performing robots.
9 + 10	Digitalisation and skilled workers	5 ECTS	The course focus on the effects for skilled workers of industry 4.0 by using video- and audio content, including the training material developed within this project	The students responded well to the form of the education, and noted that the industry 4.0 content became less abstract in the new course.
11	Product development	5 ECTS	The students should be able to integrate both consumer, technology, digitality and technology into their product development. This was supported by flipped classroom, blended learning, and online supervision.	The students reported satisfied with the form of the course, and that they had strenghtened their diciplinary and interciciplinary knowledge.
12	Virtual prototyping	5 ECTS	The course thought virtual prototyping techniques relying on simulations in a blended learning flipped classroom environment.	The students were satisfied with the course and able to use the provided tools. Furthermore, they were also able to identify new learning needs related to the topic.
13 + 14	Simulation and integration	5 ECTS	The course consisted of thermal simulation and integration with other product design tools. It relied on flipped classroom, blended learning and simulations.	The students reported medicore satisfaction in the first round, as their self-study capabilities were not on par with the requirements in the blended learning setup. This was altered in the second iteration, to the satisfaction of the second team for students.

6. Learning Outcome and Educational Characteristics

The evaluation of the 14 pilots can be aggregated into five themes; the four Kirkpatrick levels (1) reactions, (2) learning, (3) transfer, (4) performance [37], and given the circumstances of this case (COVID-19), a fifth theme is added; (5) external circumstances.

The majority of students in all pilots reported positive reactions to the organisation and content of the education. The pilots where the participating institutions performed course satisfaction evaluations, the results showed a 75–85% satisfaction with the courses. This is on par with, or above, the European average before the COVID-19 pandemic of 77% [46]. The students were explicit that they appreciated the cases and mini-projects, as well as the video and podcast material. They also reported that the educational material was well made, and that it fits the style and content of the courses. The high degree of blended learning allowed asynchronous watching of video lectures and listening to

podcasts, to which the students reacted positively. All of this contributed to a higher motivation among the students. A few students noted that the open-ended problems were frustrating, which was the only reoccurring complaint about the courseware. This implies that the organisation of the learning, as described in Table 1, provides the students with a satisfying learning environment.

In addition to the positive reactions to the course, the learning outcome was also high. In one pilot, a student noted that everyone seemed to be able to contribute with their cases afterwards and that this aided the discussion. The ability to revisit video and audio material also aided previously failed students, who highlighted this as a significant improvement compared to traditional auditorium lectures. The reflective dimension of most pilots also aided new insights. When reflective questions were part of the preparation for the day, students came better prepared for discussing the topic. The students put in much effort, combined with the authentic tasks they solved: all pilots meet their learning goals. Positive reactions regarding relevancy and motivation can explain this effect. Furthermore, the broader understanding of, e.g., business or digitalisation was also improved during the activities. Some students also reported that abstract content became more accessible and relevant through the authentic cases, helping them understand it better. This implies that the learning outcome from the structure, task type and work mode in Table 1 have fitted for the subjects.

The transfer from the explicit pilots into the general practice of the students was also seen in the evaluations. After some of the pilots, the students were asked to identify further learning requirements and pointed towards different techniques to master or knowledge to obtain. As mentioned, the students could identify further learning goals, both within the application of the learned skills and knowledge within their projects, as well as new skills to acquire. They became more aware of digital tools and solutions, and in the pilots with integrated interdisciplinarity, they also increased their understanding of other related disciplines. This transfer was also seen in some of the semester projects, which tended to be more digitally-minded than previous semesters. This support that the educational framework targets the characteristics of industry 4.0 education, as described in Table 1. The students' performance upon graduation was not evaluated within the project's timeframe, but students reported confidence in job readiness and ability to perform within the topic of the pilots.

While all the above is positive, many students noted adverse effects from COVID-19 (external circumstances), where hardware, internet connections, organisation and social interaction became challenged. All of this might overshadow potential negative feedback, as in general, well-planned and conducted courses suited for blended learning worked well. Hence, the results should be understood in that context, where minor drawbacks of the planned courses could have been eliminated under other circumstances.

With offset in these themes, it can be seen how this approach can enhance industrial learning for targeting the industry in the 4.0 movement, as described in Table 1. As seen from the learning outcome of the 14 pilots, the nature of communication (both digital and analogue, synchronous and asynchronous) enhanced the learning and, at the same time, added the technologically augmented dimension. Along the same lines, the physical and virtual tasks are also presented in this framework and support learning outcomes and transfer. The autonomous and group-oriented tasks also seem to have increased both positive reactions to the pilots and learning outcomes.

7. Discussion and Conclusions

As the industry turns ever more complex, it alters the educational setting that prepares tomorrow's workers for the industry. Hence, methods and tools for targeting this change can aid educational institutions' transition towards educating for Industry 4.0. To guide educational institutions, this paper presents an agile educational framework that combines a process model with analysis and an iterative building phase with the task-centric approach of authentic task design. The task-centric and agile education approaches have prevailed

individually within education. By proposing this combination, we presented a tool that can enhance the students' knowledge by keeping the content up to date compared to the complex industry and by providing the student with authentic problem-solving abilities. Nilsson's [29,30,39] analysis of the learning associated with the earlier industrial paradigms suggests that the educational settings affect the amplitude of learning and what is learned. Hence, the learning approach should fit the desired learning outcome in the teaching approach and have a relevant, authentic task. A known catch regarding authentic tasks is that minor details can draw too much attention. Hence, Enke et al. argue that the authentic task should not wander into details, as this leads to many technical-centric learning activities having less than optimal learning design. If tasks focus too heavily on a few technical aspects, they can leave more general perspectives behind [25]. The iterative approach presented in this paper can limit this wandering, as the iterations will identify this. If the technical details are too pronounced, this can be adjusted in the next iteration.

The analysis shows that the industry requests ever-increasing competencies outside the traditional technical domains, the student's learning, personal, and interdisciplinary skills gain further traction. This Educational Framework supports this by suggesting multidisciplinary student groups. As suggested by Prensky, this work targets several fundamental learning areas: creative thinking, problem-solving, system thinking, mindset, innovation, collaboration, and communication (Prensky, 2014). Neither of these competencies are necessarily required to perform a specific industrial task. As they are not core competencies, they aid the overall task solving. Hence, they are contextual competencies [9] that can aid the worker in everyday tasks.

While this educational framework provides tools for designing new educational activities for educators in higher education, specifically for learning Industry 4.0 skills, then the educational framework should be tested in other contexts where multidisiplinarity is key, and learnings can be supported by authentic task design. In addition, future work should specify two things: (1) Deeper case studies, which can provide details on how to use the framework and why it works, along with (2) test in further education, an other important area for industry 4.0 competence development. A limitation to the study is found in its uses in areas with a more strict requirements for what the learning outcome should be, such as law or healthcare, meaning that the everchanging nature of the task-centric educational framework cannot support this material, but the methods and guides created could still be used to improve the teaching methods.

The proposed Educational Framework is a tool for educators to create educational content targeting future industries, which have in this study been tested across various European countries. According to cultural studies [47], this multidisciplinary way of working is culturally fitting these countries, however, exploring how the adoption and use of the educational framework can be used across countries is highly relevant. This aligns well with the call for a Industry 5.0 or Society 5.0 agenda [14].

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: The data can be found at on www.teffic.eu (accessed on 21 September 2022).

Conflicts of Interest: The authors declare no conflict of interest.

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