Yuhua Luo (Ed.)

Cooperative Design, Visualization, and Engineering

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Virtual Event, September 25–28, 2022
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Preface

The CDVE 2022 conference was planned to be held in Krakow, Poland. Due to the COVID-19 pandemic and the current situation in Europe, we have unexpectedly changed it to a virtual and online conference for the third year. CDVE 2022 was held during September 25–28, 2022, hosted online by the Jagiellonian University in Krakow, Poland. The conference is under the Honorary Patronage of the Rector of Jagiellonian University.

This volume contains a collection of the papers accepted for the 19th International Conference on Cooperative Design, Visualization, and Engineering - CDVE 2022. Over a hundred authors from 16 countries submitted papers to the conference.

As we can see from the contributions in this volume, during this period of turbulence, our researchers worked extremely hard. Convincing research and development results cover a very wide application spectrum. The areas covered by the papers include architecture, engineering and construction (AEC), spacecraft building, heavy industry, robotics, tourism, education, community building, the medical supply industry, commerce, etc.

In the application area of AEC, automatic or semi-automatic information extraction, business rule translation, representations allowed by BIM, etc., are under study. Urban planning is one of the hot topics for the study within this area. Protection of the environment has been considered as a priority in urban planning. One paper develops a prototype of a cooperative framework for incorporating the reduction of air pollution into urban design. Another contribution reports on experiments in wayfinding within historical districts to analyze the design focus for urban areas. Related to urban planning, for the benefit of heritage information dissemination, crowd sourcing is applied to cooperative information collection for local heritage sites.

A number of papers in the volume concern vocational and work training. To design better upskilling training programs, stakeholders are invited into the co-design process. Higher quality presentation forms such as immersive 360-degree videos are also used. The education material is created by collaborative teams.

In the areas of visualization and visual analytics, one paper reports the study of fusion and visualization for GIS in multi-scenario cases. Another paper about using a visual analytics approach for crane anomaly detection based on digital twin opens up more possibilities for the application of visual analytics to many industrial scenarios. Progressive visualization of mass parameters during concurrent engineering for spacecraft design answers the challenges we face in cooperative visualization. In another study, the visualization of data structure serves as an aid in collaborative game design. This example shows that visualization is a great tool for software development, which is typically a process of collaboration.

A number of papers in this volume target companies and their need for knowledge and information administration, providing flexibility for small and medium-sized enterprises in their process towards setting up their information technology infrastructure. These infrastructures include secure communication protocols for tiny IoT devices and the Industrial Internet.

To improve existing cooperative working tools, one paper in the volume performs an empirical usability study on the popular video conferencing tool Zoom. It evaluates the current version, focussing on its collaboration with newcomers. The paper analyzes the problems and offers recommendations for improvement.

Cooperative technology can open up new possibilities and an example of this is given in a paper addressing wireless energy networks and showing how cooperation can extend to energy supply in such a network.

On the subject of human-machine interfaces, the proceedings include a study focusing on a very special way to interact with a computer by human eye movement tracking through Electro-Oculography (EOG). These are valuable research resources for people working in this area.

Papers involving basic methods and technologies for cooperative applications presented some work about the use of convolutional neural networks applied to different scenarios. The application scenarios are so different that one aims to classify URLs in the Internet while the other aims to retrieve recipes for Thai cuisine. Both reach their goal successfully.

Last year we thought that the pandemic had lasted longer than expected. This year we feel that this is a challenge we may always have to face. This might be a result of global climate change, which triggers worse weather conditions and worse human diseases. We should pay more attention to protecting our environment. The CDVE community has been working hard for better technology and better environmental protection for our wonderful earth. For this, I would like to express my sincere thanks to all the hard-working authors for submitting their papers to the CDVE 2022 conference. My thanks also go to all our volunteer reviewers, Program Committee members, and Organization Committee members for their contribution. My special thanks are dedicated to the Rector of Jagiellonian University in Krakow, Poland and his wonderful organization team at the university led by Professor Ewa Grabska. The success of this year's conference would not have been possible without their support.

September 2022 Yuhua Luo

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Co-design of Technical Upskilling Training Program Through Early Stakeholder Involvement

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Abstract. The present and future digital transformations of industry 4.0 set a high skill requirement for workers. This skill requirement calls for upskilling, a change in job profiles, and lifelong learning, both for the worker, the workplace, and society in general. However, for upskilling activities to leave a lasting impact on the behaviour and skills of the worker, the upskilling needs to be authentic, relevant, and valuable. Unfortunately, many traditional upskilling activities, such as coursework and lecturing, do not meet these demands. This paper investigates how the early involvement of stakeholders in the process of Industrial Collaborative Educational Design (ICoED) can contribute to authentic, relevant upskilling of industrial workers. The article takes a point of departure in industrial, educational research and investigates how educational authenticity benefits from the co-design process.

Twenty-one upskilling workshops across seven pilot projects in a number European countries are evaluated focusing on how the stakeholder-involved co-design process enables authenticity, relevancy and value. The results indicate that both realism and applicability were obtained. Furthermore, it is discussed how this type of engaging activity can ensure worker ownership and transparency of the upskilling activities by raising the worker's voice and how these principles can be applied in other and further upskilling activities.

Keywords: Upskilling · Co-design · Stakeholder involvement · Educational design

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1 Introduction

While hard technical skills have always been a critical requirement for industry workers, this requirement is still increasing due to the digital overlay added on top of traditional, e.g. manual jobs [1]. As workers already possess several of these skills, the workforce is a valuable asset for any manufacturing enterprise, but this asset does also need maintenance and upgrading. Specific skills age and become obsolete, and other skills emerge as necessary in order to perform a given task. This is particularly driven by digitalisation and automation, where employees engage with new technologies to perform previously paper-based or physical tasks [2].

This change in the skill requirements can cause a gap between the skills the worker possesses and the required skills [3]. This gap is even more comprehensive as the focus on contextual skills also increases [4]. There are two possible ways to address this: full time education of (mostly) young students and further education of the existing workforce. The full time studies can be both vocational education and higher education, but as competencies still age, these can also become obsolete. Furthermore, due to e.g. life situation with family and economic obligations, many workers hesitate to enroll in full time education. Further education stands out as a path to lifelong learning, rather than traditional learning at the start of adulthood, which should last for the rest of a career. Hence, lifelong learning is of interest to maintain a more capable workforce.

Earlier approaches include lecturing, apprenticeship and different types of courses [5]. However, these have often been anchored in less-than-optimal didactical settings, based on a laboratory-like setup where isolated exercises have been conducted with a weak link to the industrial context and limited previous knowledge of the worker [5]. Along the same lines, traditional lecturing is also a less-than-optimal approach for this type of lifelong learning, as it mainly demonstrates new knowledge without activation of prior knowledge [6]. This type of activation needs to be incorporated through reflection, which can be difficult in a traditional one-way educational setting, that does not target individual learners with custom-made material.

One solution for activation of prior knowledge is to create authentic learning material, which enables the workers to learn based on examples, exercises, and methods related to their everyday work life. This has been proven effective within both authentic task design [7,8], the First Principles of Instruction, [9] and communities of practice [10]. However, this is not a trivial task. It requires a deep insight into a field to create authentic educational material. Hence, it can be a barrier to creating authentic educational material in fields where the educational designer does not have first-hand experience. A way of overcoming this barrier is to co-design the educational material, specifically by inviting workers, managers, and other stakeholders to present proposals and give feedback on authentic, relevant learning goals, activities, and methods.

In this project, we aim to include the voice of the learner and other stakeholders for increased authenticity. This relies on the assumption that these learners and stakeholders can be considered knowledgeable within the scope, if not the

content, of the upskilling [17]. To do so, we use a co-design process called Industrial Collaborative Educational Design (ICoED). This enables us to answer the question: "How can the authenticity of further industrial education be increased through co-design with workers and other industrial stakeholders?".

The paper proceeds with an introduction to the methods used and the ICoED process. It is then described how ICoED was implemented in 7 learning activities and tested during a total of 21 pilot projects. The obtained insights are summarized and underlined with relevant quotations from the participating stakeholders in a subsequent evaluation and discussed in the context of the relevant theory.

2 Methods

This research for this paper was performed as engaged scholarship [11,12], with a dual purpose. To improve further education and lifelong learning of industrial workers, and to generate new knowledge about authenticity of education. Engaged scholarship enables the research to be structured around the problem of upskilling, and at the same time answer the research question. To achieve this, a three-step approach was applied.

1. An initial mapping of skill profiles and trends within industry. See Pontes et al. [13].
2. Development of a co-design method for industrial stakeholders and other education professionals. See Geraldes et al., [14]. The stakeholders are, in a narrow sense, workers, managers, and directors. However, this can be extended to industrial agencies, unions, and other stakeholders in a wider sense.
3. Practical use and evaluation of the tool and the resulting learning activities in six European countries through seven industrial further education activities. Each of these consisted of 3 workshops, adding up to 21 in total.

These three activities/workshops were evaluated in correspondence with the FEDS model for design science research evaluation [15]. This means that the experiments move into a naturalistic environment with a high pace, and maintain formative evaluation to ensure compliance with e.g. positive reactions to a further education activity. This also corresponds with the first Kirkpatrick level, where the reaction to the teaching is important to the overall result [16]. The process could be summarised as follows:

1. The background analysis relies on a mathematical formulation of the skill requirements within a given sector, combined with a mapping of existing further education activities across the European Union. These mappings and the mathematical formulation were combined into a proposed tool for identifying the skill gaps and profiles of industrial workers.
2. The proposed ICoED method was developed from a previous CoEducational Design model (CoED) [17]. The model was tested in the design of the seven further education activities.

3. The facilitators evaluated the model after the end of the design process. This was a semi-structured interview evaluation, where the workshop participants both commented on the function of the model and the resulting educational material.

The ICoED process brings together the knowledge and experience of diverse, but still context relevant, chosen stakeholders to collaboratively contribute to the design of learning solutions and thereby meet current and emerging needs. An overview of required stakeholder participation is seen in Fig. 1. In this project the chosen stakeholders were:

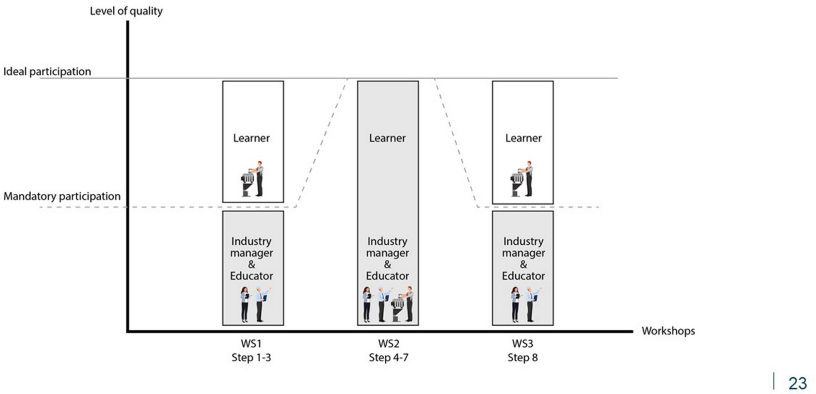

Fig. 1. An overview of the required learners in the three ICoED workshops.

– Industry Managers
– Workers/Learners
– Educator/Educational partner

The chosen stakeholders can be workers, unions, middle management, management, owners, industry associations, educational institutions and so on. In terms of meeting a high level of quality and ensuring having knowledgeable participants to contribute with their specific knowledge, the following stakeholders are, as a minimum, recommended:

– Industry manager - to provide the knowledge of the specific industry the upskilling is intended for.
– Workers/Learners - to provide the knowledge of the process or the specific tool, machine or process the upskilling is intended for.
– Educator - to provide the knowledge of upskilling, teaching and needed learning theories.

As shown in Fig. 1, there is an ideal level of participation, which involves all the participants in the entire workshop process. It is especially recommended to involve the actual learners in the whole process since they are the target group and therefore very important. The mandatory level of participation demands that learners are part of at least one workshop. Ideally the learners participate in the second workshop where the largest chunk of the content for the upskilling program is defined.

The ICoED method and process focus on user involvement, collaboration, and dialogue. It is a way of co-designing learning activities structured by pre-designed supportive cards with preprinted statements and contextual words or blank cards. The cards help articulate factors relevant to learning goals, learning approaches, and technical and domain-related issues. The use of preprinted (and blank) supporting cards gives the option of a very open and loosely structured collaborative dialogue. This dialogue, combined with a co-design approach, reveals each participants subjective view on the motivations for upskilling and develops a shared understanding of the topic. The different stakeholders participate on an equal level, and their role is to contribute to the process with their own knowledge within the specific industrial upskilling area. The educational level or job profile of the stakeholders is not important here, but the different views, needs, and understandings, that should create a better fit for everyone when combined, are. This shared understanding can be used to identify areas suitable for modular design approaches, and ensures that the end product is a more or less fixed final blueprint. An example of such a blueprint can be seen in Table 2.

The co-design process is divided into three workshops and eight steps. The first workshop focuses on learning objectives in steps 1–3, the second workshop focuses on learning approaches in steps 4–7, and the third workshop focuses on course structure in the final step 8. The workshops are conducted by trained facilitators supporting the invited stakeholders through the process. The workshops can be held in a physical environment or online. In this article, we touch on the process of 21 online workshops and the data gathered from those. An overview can be seen in Table 1. For further information, see Geraldes et al. [14].

The evaluation of the workshops is in the form of an interview with the facilitator. It aims at obtaining knowledge of the experience of the workshops and the resulting educational design. The interview is semi-structured, so the interviewer ensures that all areas are discussed [18].

3 ICoED Implementation and Experience

The seven pilot projects are listed in Table 1. These pilot projects were conducted in cooperation with seven project partners in six European countries. The experience of the online educational design model was an overall positive one and the stakeholders interviewed in the evaluation mentioned several traits they liked. Participation in the process was easy and engaging due to the active facilitation of the discussion. Hence, dominating behaviour of a stakeholder, who,

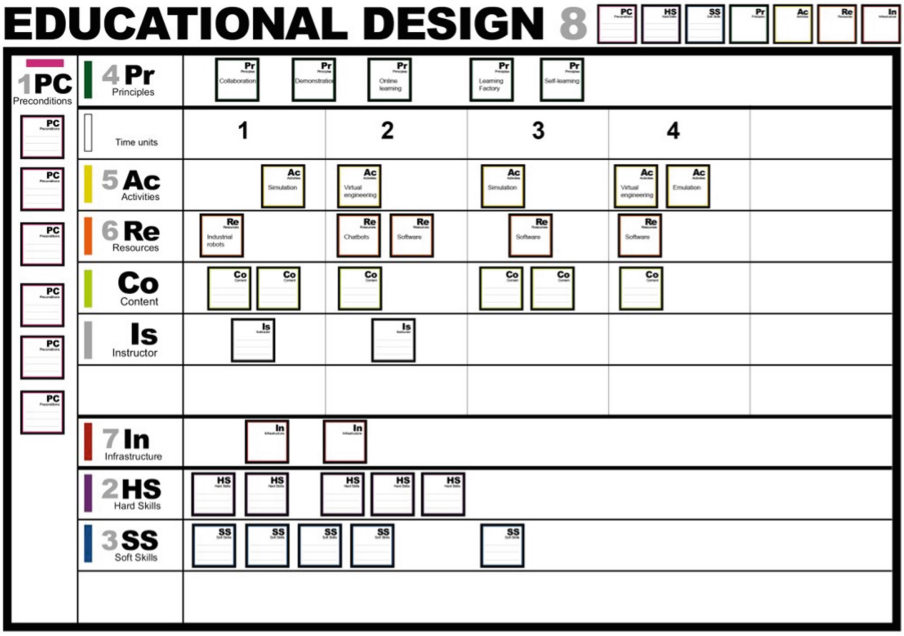

Fig. 2. An example of an educational design generated through the ICoED process. The output is planed with phases, learning activities, and skills.

Table 1. Description of the ICoED process. For further details, see Geraldes et al. [14].

Step 1	Input: Limitations, requirements and information for the learning activity Outcome: A description/characteristic of the learner and the context
Step 2	Input: List of hard skills relevant for the worker or position of focus Outcome: Hard skill-oriented learning goals
Step 3	Input: List of soft skills relevant for the worker or position of focus Outcome: Soft skill-oriented learning goals
Step 4	Input: Results from set 1–3 Outcome: Dominant learning principles for the educational activity
Step 5	Input: Dominant learning principles from step 4 Outcome: Highest prioritised learning activities to activate these principles
Step 6	Input: Prioritised learning activities from step 5 Outcome: Needed resources to facilitate the activities
Step 7	Input: Prioritised learning activities from step 5 Outcome: Needed infrastructure to facilitate the activities
Step 8	Input: Principles, activities, resources and infrastructure from step 4–7 Outcome: Educational design

if permitted, would do most of the talking, and thereby define the educational design without input from many others, was avoided in favour of a discussion involving the whole group. According to the participants, this leads to valuable and authentic educational designs that can be used as a basis for forming the actual educational material. Furthermore, the participants rated the new educational designs more authentic than e.g. traditional lecturing.

Table 2. Description of the seven pilot projects

Pilot 1	The pilot project focuses on educating industrial operators from a Romanian household appliance manufacturer The learning is recognised within their internal competence management, and will target technical and human requirements for a given job role. This includes a focus on mixed, hard, and soft skills
Pilot 2	The target group are shop floor employees in a medical factory in Ireland The pilot is part of an internal upskilling program, which is compatible with the Irish system for recognition of prior learning. The topic is change management in relation to a production line
Pilot 3	The target group consists of technicians from manufacturing SME's in northern Denmark. The pilot project is a formal course valued at 10 ECTS, with the topic Value Chain understanding in relation to innovation, product development, and production
Pilot 4	The pilot project targets technicians at a Portuguese car part manufacturer. The learning activity offers internal recognition, and provides hard, and soft skills related to robotics, connectivity, and data analysis
Pilot 5	The target group consists of automation technicians in the French industry. The activity will be recognised at EQF level 6, with learning goals concerning system diagnostics and data analysis
Pilot 6	The pilot project targets older workers and women from SME's in a northern Italian industry cluster. The activity offers no formal recognition of the learning. The learning goal is enhanced smart production skills
Pilot 7	The target group consists of women, junior and senior workers in the Galician automotive industry. The pilot project offers no formal recognition of the learning. It aims to provide soft and hard skills for industry 4.0

Firstly, the ease of use allowed the stakeholders to participate, and the level of participation surprised the stakeholders. The amount of prior knowledge needed to participate in the co-design process is low, insofar as the stakeholder has a fair overview of the everyday work life of the person enrolled for the upskilling. While it is possible that some stakeholders might not have any such overview, the experience gathered during the workshop was that most did. The ease of participation is expressed in this quote from the third pilot project:

> "The ICoED model is very user friendly and very easy to use. You do not need much information to participate, because you learn along the way. We were surprised to see a level of participation as high as it was. Everyone participated and the dialogue was very constructive, also from the participants that we had not met in real life before." - Pilot 3

However, to achieve this ease of use, facilitation was important. See the quote below from the second pilot project. More assertive workshop participants can overshadow less loquacious stakeholders, and power structures can also play an important role. For instance, a worker could hesitate to argue against the boss, or an active union member could overshadow an introvert middle manager. As loudness and insight are independent variables [19], this calls for solid facilitation to achieve authentic learning environments. Furthermore, the facilitator also needs to empower the participants to share their knowledge and expertise, or else the effort will be in vain.

> "The Facilitator helped with the ongoing dialogue. A strong facilitator is needed, one who guides, helps and keeps track of time. The facilitator can push and challenge people and set up the rules and expectations. For example: cameras are turned on and active participation is required." - Pilot 2

One important part was the involvement of the workers as stakeholders. In the first pilot project, this involvement had previously been through questionnaires, but by changing to the workshop format, the voice of the learner became more pronounced. This is seen in the quote below from pilot 1, where the participant notes that it was interesting to participate, and especially insightful compared with the previously used method.

> "When involving the workers we give them a voice. Before this ICoED process we involved them by questionnaires. Now we can involve them via both. We found the process very well organised, and the facilitator also helped us forward if we got stuck. A facilitator is initially important, but we believe that we can learn to run our own workshops as well. The final design is amazing - before we didn't think this was possible. It is very new to us; we have never tried this before, and we are impressed by the methods, because it was fun, easy and we got so much out of it". - Pilot 1.

Incorporating the co-design process into the design of educational activities has given a clearer image of the application environment of the learned skills. Hence it enables courses to be more authentic, and at the same time, it makes it easier to go from educational design to educational content. This can be seen in the following quote from the third pilot project. Along the same lines, the use of blank cards enabled the workshop participants to, by themselves, both group related themes into clusters and introduce new ideas which had not been identified during the preparations for the first workshop.

> "We found that the workshops have helped us in getting input from outside. It helps us widen our perspective, and we start to investigate the

needs of the learners and the industry. We have gone through the final step (step 8 - overview) and we now design our course from the input and output of the ICoED workshops. As guideline it is perfect." - Pilot 3

While the framework in the ICoED process is flexible, some participants note that it is important to adapt to material to the audience. The variety between different cultures and learning environments needs to be considered in the facilitation, as seen from the evaluation of the fourth pilot project.

"ICoED methodology is method that could be expanded within our Group, and probably even to our sector. Of course, this would require some adaptation to the reality of each facility and country but the framework is robust enough to be easily expanded." - Pilot 4

4 Discussion

Based on these insights, we conclude that the ICoED workshops has more positive effect to offer in regards to designing authentic learning activities than traditional course planning without stakeholder involvement or e.g. designs based on questionnaire data collection. As seen in the following quotes from pilot 3 and 4, some of the workshop owners had not started involving the workers in the upskilling planning, even though they were aware of potential benefits. Hence, the process can be a part of the solution to closing the skill gap experienced since the advent of industry 4.0.

"The ICoED process has helped us to solve, in only a few months and three workshops, what we have struggled to solve over several years." - Pilot 3

"The ICoED process was a good experience which helped us transition from a traditional approach to the upskilling needs and the identification of training programs, to a dynamic approach where the different steps of the process contribute in creating an organic program through the use of brainstorming technics, team work, decision making and optimization." - Pilot 4

Furthermore, when a specific stakeholder was not present, it became evident that the other stakeholders were inclined to take their point of view. E.g. if no industrial worker were present, the manager of these workers would often take their point of view and reflect upon what the learner would have expressed. This means that the process is less sensitive to absentee learners. However, the process will undoubtedly suffer if taken to the extreme, and if collapsed to a single person trying to do the workshop in a theatre of the mind, it would resemble classic planning tools for education. The workshop participants were aware of this, as seen from the following quotes from the second pilot project.

> It is important is to have participants with different understandings and expertise. The workshops shifted between formal and informal. It makes people feel comfortable talking and thinking out loud. There were cards with statements about learning and learning technologies, which may not be readily understood by all participants (technicians) and therefore will weaken their ability to participate and fully relate. The cards, and the design and placements of the cards, end up telling a story, creating a visual overview or a visual learning path. We really liked the fact that we work with both skills, competences and activities and the interconnection between those." - Pilot 2

Power relations can potentially be a challenge in the co-design process if two stakeholders have opposing views and one is more influential than the other. During the course of the workshops it became evident that those workshops that aimed for a generalized project, with no specific relation to a single factory, had less observable power relations than those aimed at a specific company. However, the ICoED process and facilitation still allowed all stakeholders to participate in the co-design process. The participants can minimize the effects of this challenge by imposing speaking orders and actively questioning quiet participants.

Reeves et al. [7] mention 10 recommendations for authentic task design, and the ICoED process contributes to 5 of these. First and foremost, the process ensures that the course has real-world relevance, and this even in the narrow sense of the worker's everyday work life. Furthermore, the knowledge of this work life allows the educational designer to create course content with open-ended and wicked problems, which the learner should investigate within their practice. The co-design process also gives several interpretations on the problem for which the upskilling was needed, allowing for a task design with different perspectives. These different perspectives also establishes a space for reflection, which can be further aided by discussion among the learners and a broader explanation of findings [20]. The integration and application of the obtained knowledge would also be ensured. With a practical foundation and reflection thereon the learner is allowed to activate prior knowledge and first apply, then integrate into their practice, the demonstrated knowledge [9].

Several elements of the ICoED process support the development of relevant material. First of all, the online environment acted as a good stage, allowing collaboration over large distances, but also as a fertile breeding ground for ideas. The workshops enable the mix of digital artefacts and known skills, principles and learning activities to be shaped and reshaped by the stakeholders. Hence, the online room can be seen as a space where the educational designer learns about the authentic application space [21]. Along the same lines, the open-ended cards in addition to the stage set by the prepared ones, allow the workshop participants to enrich the shared knowledge in the design process [22].

While these experiments with the co-design process have produced satisfying results regarding educational design and authenticity, the limits still need to be explored. Several other methods exist to achieve higher authenticity, e.g. learning factories [23,24] and gamification [25]. While the works of Merrill might indicate

that the co-design process can contribute to giving a clear overview regarding which prior knowledge to activate, it remains still to be tested whether the ICoED method is on par with other, competing methods.

Lastly, regarding ICoED as a solution to upskilling design, the facilitator role does not scale well. If the process needs to be used as a general solution to create more authentic further education activities, the required number of facilitators will be a challenge. However, a well-defined guide to the process and online support can enable those within education and enterprise, who act as facilitators of other processes, to gain competency in the method.

5 Conclusion

The use of the co-design process, in the form of the ICoED method, has a positive effect on the authenticity of upskilling course design. The process made two contributions to this authenticity: deeper insights and a wider range of perspectives. In combination, they serve as a solid basis for creating authentic course design, allowing for the execution of more authentic upskilling activities in the future. These authentic course designs would have been hard to achieve without the stakeholders. Furthermore, the participants enjoyed the process, and expressed confidence that the educational designs were improved compared to the products of other methods used for this design process.

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