Design Factory – Supporting technology students' learning of general competences through university-industry collaboration

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Many studies emphasise the need for supporting higher education students to develop general competences. In this study, we report on the first cycle of a design-based research project conducted in the Design Factory context. The aim of the project is to understand how general competences can be integrated into course modules and within university-industry collaboration in a successful way. In this study, we report on a theoretical problem analysis and describe the design solution, namely the Design Factory implementation. We then move on to an empirical problem analysis and investigate how students reported developing general competences in the implementation. When discussing the implications for further developing the design solution, we conclude that communication has a vital role in university-industry collaboration; it is essential in clarifying the multilevel learning opportunities (e.g., the subject content, development of general competences) for students, and in aligning industry interests with educational learning objectives. We also reflect on the first development cycle as a whole and provide implications for refining the design process. Finally, we draw conclusions from the whole DBR project and provide a new theoretical perspective (cf. Edelson, 2002), namely design-based education in the co-creation contexts, that can be utilised when investigating the development of general competences in the Design Factory context.

Keywords: Design Factory, technology education, university-industry collaboration, general competences, design-based research

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1 Introduction

In recent years, higher education researchers have emphasised the need to develop students' general competences already during their higher education study. General competences can be defined as a multidimensional set of skills, attitudes and behaviour that can be broadly applied to a range of disciplines or circumstances (Strijbos et al., 2015; Tuononen et al., 2019; Tuononen & Lindblom-Ylänne, 2017). Tuononen and colleagues (Tuononen et al., 2019) identify general competences as a central factor related to students' employability as well as career success, and that promote higher education teaching that supports the development and awareness of general competences in students. Prior research acknowledges the possibility of supporting the development of general competences with teaching interventions; however, instead of isolated academic competence or study skills courses, it is more efficient to learn general competences together with subject content (Schaeper, 2009). Therefore, it is important to understand how pedagogical practices can respond to the dual goal of both learning the subject content and developing general competences.

To address this dual goal and the close connection between developing general competences and working life, we conduct design-based research on technology students' learning in authentic work-like settings as provided by the HAMK Design Factory. The HAMK Design Factory, established in 2019 and a member of the Design Factory Global Network, is an innovation platform embodied in authentic university-industry collaboration and the notion of co-creation pedagogy (Jussila et al., 2020; Kunnari et al., 2019). Authentic university-industry collaboration refers to mutually beneficial knowledge and technology exchange between higher education institutions and industry stakeholders (Jussila et al., 2020). This collaboration also influences the pedagogical practices of the Design Factory. Kunnari and colleagues (Kunnari et al., 2019) argue that the Design Factory concept requires a redesign of work from all stakeholders; therefore, a new pedagogical approach is also required to investigate learning within the Design Factory implementations. This new pedagogical approach draws on the notion of co-creation pedagogy, an extension of competence-based education (Geitz & de Geus, 2019) that captures the main interactions and activities between students, teachers, and industry (Kunnari et al., 2019). In other words, co-creation pedagogy makes it possible to address the need for authentic university-industry collaboration and provides opportunities for the development of general competences. By researching learning within the Design Factory concept (Björklund et al., 2019), we promote technology education that supports both students' learning in higher education institutions and their subsequent transition to working life, but also the idea that it is both current and valuable to understand how practice and theory, teachers and students, and university and industry come together to learn in a meaningful way.

1.1 Design-based research

Design-based research (DBR) is a recent method of conducting educational research. It originates in Ann Brown's work (Brown, 1992) and the amount of research reports utilising the design-based approach has substantially increased during the 21st century (Pernaa, 2013). Traditionally, teaching practices and educational research have been viewed as separate endeavours (Juuti & Lavonen, 2006). This is transformed in DBR as it addresses the gap between theory and practice through iterative theory-based development of education in authentic settings (Collins et al., 2004; diSessa & Cobb, 2004; Juuti & Lavonen, 2006). It is notable that DBR is not education development solely based on experiences but, by characterising the learning situation in all its complexity, it shares the dual goal of refining both theory and practice (Barab & Squire, 2004; Collins et al., 2004; diSessa & Cobb, 2004; Edelson, 2002; Pernaa, 2013). DBR requires an inclusion of a design solution, an educational practice that is being researched and developed in an iterative design process. Therefore, DBR produces three different types of knowledge: knowledge about theory, knowledge about the design process, and knowledge about the design solution itself (Edelson, 2002). DRB has gained popularity especially in STEM fields (Hannula, 2019; Juuti & Lavonen, 2006) and in contexts with technological interventions (Anderson & Shattuck, 2012). This makes DBR a suitable methodological choice to investigate the Design Factory implementations. Furthermore, DBR supports the aim of engaging in long-term efforts in understanding how students develop general competences in university-industry collaboration and in developing educational settings that support such endeavours.

1.2 The present study

The overall aim of the DBR project is to understand how to integrate general competences into course modules and within university-industry collaboration in a successful way. The DBR processes can be very long and therefore it is recommended to divide the project into phases that are reported separately (Juuti & Lavonen, 2006). We follow this recommendation and, in this study, report on the first cycle structured in accordance with the DBR process. First, we report on a theoretical problem analysis that addresses the possibilities and challenges present in the development of general competences in university-industry collaboration. Second, we describe the design process and the first version of the design solution – the Design Factory implementation that is being developed in the DBR process. The second stage aims to address the following research question:

1. What kinds of general competences do students report developing in authentic course-level university-industry collaboration?

Third, we report on an empirical problem analysis conducted on the first implementation and answer the first research question. This stage provides knowledge about the design solution (Edelson, 2002) and ways to improve it for the next iteration. Fourth, we move on to the general discussion where we reflect on the first development cycle of the DBR process and address the second research question:

2. How could we refine the design process to further support students to develop general competences in authentic course-level university-industry collaboration?

By reflecting on the lessons learnt, we provide knowledge and process-level modifications of the design process (Edelson, 2002). Finally, we draw conclusions from the whole DBR project and provide a new theoretical perspective (Edelson, 2002) to be utilised in the next iteration cycles.

2 Theoretical problem analysis

The aim of the theoretical problem analysis is to address the possibilities and challenges present in the development of general competences in university-industry collaboration. To characterise the intended learning outcomes of the DBR project (Edelson, 2002), we first address the notion of general competences. The concept of general competences is vague, and there is a variety of terms that have been used to describe them, such as professional, transferable, or graduate competences – or skills. This has created semantic confusion in conceptualising general competences and its meaning (Barrie et al., 2009; Tuononen et al., 2019). This shows for example in the various ways general competences have been measured in the literature (Kember & Leung, 2005; OECD, 2012; Tynjälä et al., 2016). The semantic work is still ongoing, as general competences are an important future research area (OECD, 2018).

Due to the semantic challenges, researchers have suggested that general competences should be conceptualised in a disciplinary context (Biggs & Tang, 2011; Chan & Fong, 2018; Jones, 2009; OECD, 2012). Therefore, the multidimensional set of skills, attitudes and behaviour that form the core of general competences (Strijbos et al., 2015; Tuononen et al., 2019; Tuononen & Lindblom-Ylänne, 2017) is captured in the present study through utilising the categorisation provided by Mikkonen and colleagues (Mikkonen et al., 2018). This categorisation was chosen because it arises from a similar context in which the present study was conducted – the Design Factory context. Their results indicate that in a Design Factory context, students developed general competences that could be grouped into four broader categories, namely Interpersonal skills (e.g., teamwork, communication, and collaboration), Attitudes (e.g., confidence or curiosity), Product development (e.g., product development and design processes), and Project management (e.g., people and task management) (Mikkonen et al., 2018). The categories and their subcategories are presented in Table 1.

The development of general competences is one of the higher education learning outcomes (Barrie et al., 2009; OECD, 2012). The implementation of general competences in the higher education curriculum is critical for a variety of reasons (Freudenberg et al., 2011; Greenbank et al., 2009). Firstly, students who have developed general competences have better graduate employment prospects (Caballero et al., 2020; Healy et al., 2020; Tuononen et al., 2019). Moreover, general competences are transferable; discipline-based knowledge can become outdated or not applicable, but general competences can be transferred into new career paths (Kavanagh & Drennan, 2008). As future work is characterised by increasing digitisation and industrial automation, the transferability of competences is further emphasised in technological fields but also in the growing number of fields applying technical knowledge. In essence, new technology-driven practices expect the future workforce to employ competences that are not yet known or taught by today's educational institutions (Freudenberg et al., 2011).

Despite the critical role of general competences for students' success in the world of work, several studies have revealed that such competences have not been emphasised enough in higher education (Tynjälä et al., 2016). In the Finnish context, only 40 percent of the students develop their general competences up to a good level during their undergraduate study (Ursin et al., 2021). To continue, the former Finnish UAS students have reported lacking skills needed in the world of work, especially related to problem solving, handling stress and adjusting to new situations, organising and coordination, and communication and negotiation (From UAS to Career, 2020). In fact, it has been stated that there is a considerable difference between what is offered by the educational system and what the labour market actually needs (Mavromaras et al., 2013). Also, students can find it difficult to identify and describe what kinds of general competences they have acquired during their higher education study (Tuononen et al., 2019) and challenges in recognising the development of these skills may have negative effects on students' employability (Tuononen & Lindblom-Ylänne, 2017).

Despite the challenges of emphasising and recognising the development of general competences, prior research indicates that the development of general competences and an ability to identify them can be supported for example through reflective, deep-level learning (Tuononen et al., 2020). The educational dimension of university-industry collaboration is usually described from the perspective of research projects emphasising the role of personal relationships and shared sense-making between the student and the industry partner (Kunttu, 2017; Kunttu & Neuvo, 2019). However, it is not clear in the literature how these two aspects – students' reflective deep-level learning and university-industry collaboration – can be combined effectively in course-level implementations to support the development of general competences.

3 Design procedure

In this section, we present the design processes and the people involved in it. The starting point for the design process was an existing study module in the curriculum of the School of Technology at HAMK. The second author from HAMK Design Factory joined efforts with the third author, and together they integrated student projects conducted in university-industry collaboration to the existing curriculum. In doing so, they realised that they have expertise in coaching students on university-industry collaboration but lack knowledge in assessing and further developing the implementation. Therefore, the team was extended to include educational experts.

The people involved in the DBR project have a variety of relevant expertise. We have assembled a team that consists of educational experts (first and fourth authors), the head of HAMK Design Factory (second author), and the teacher of the course module (third author). By sharing our expertise, we can address the design process and teaching and learning of general competences in an authentic university-industry collaboration from multiple complementary perspectives. The design process was initiated by the second and third authors and at the end of the first implementation, the first and fourth authors joined the team to investigate the students' learning experiences. The reflection and conclusions for the next iterations were conducted jointly.

4 Design solution 1.0

In this section, we report the course implementation that represents our initial idea as a response to the challenge of supporting the development of general competences in an authentic course-level university-industry collaboration. Orienting frameworks that guide the design process (diSessa & Cobb, 2004) include co-creation pedagogy and design thinking.

The orienting framework of design thinking draws its inspiration from the Design Factory Global Network (DFGN), which HAMK Design Factory joined as the 25th member. In the beginning of the year 2022, Design Factory Global Network consisted of 35 innovation hubs in universities and research institutions around the world. During the International Design Factory Festival in 2021, a yearly meeting of Design Factories, the network included a total of 204 staff, 6675 students, and 651 student projects taking place in 25 countries. Design thinking is used in many DFGN student projects as a guiding framework for students learning. Co-creation pedagogy framework was developed to describe the Design Factory pedagogy at HAMK (Jussila et al., 2020; Kunnari et al., 2019).

The implementation applies co-creation pedagogy, especially in the way university-industry collaboration is organised. Co-creation pedagogy emphasises the collaboration between students, teachers, and industry representatives (Jussila et al., 2020). Drawing from competence-based education, co-creation pedagogy acknowledges the need for students to apply knowledge in practice, instead of only accumulating knowledge (Biemans et al., 2004). This implies that the context of learning is co-designed with industry. Students work on problems in authentic university-industry collaboration, where problems are both current and relevant for the industry but also aligned with the intended learning objectives (Biggs, 1994) of the course module of the university. In this vein, the central idea of co-creation pedagogy is to match industry needs with students' competence development as outlined in the course modules. The modules steer the challenges and problems sought from industry and the competences that are the object of development. Teaching and guiding are planned to support students' activity in the professional domain; these activities are manifested as prototypes of a professional product, and these activities are also assessed. However, in contrast to competence-based education (Geitz & de Geus, 2019; Projectbureau Competent HTNO, 2000), assessment in co-creation pedagogy emphasises how the intended learning objectives are achieved, rather than the quality of professional product or professional behaviour. Co-creation pedagogy is further distinguished from competence-based education in that industry resources are utilised in the students' activities. As a practical example, to solve a problem related to industry data analytics, the students need data from the industry and opportunities to interact with industry experts to make sense of the data.

Co-creation pedagogy orients towards design thinking. Design thinking is applied in the design of the learning environment and its activities. A key element of design thinking is the user's view that is taken as the main starting point for the problem-solving processes. Design thinking adds an essential element to problem-based learning by paying more attention to the problem and solution space; in design thinking, the solutions should be desirable from the human (user) point of view, feasible from the technical point of view, financially and economically viable from the organisation's point of view, and sustainable from the environmental and societal point of view (Geitz & de Geus, 2019; Jussila et al., 2020; Plattner, 2010).

In the implementation, the students develop a prototype of a visualisation and data analytics solution for the problem presented by industry. The eight-week data analytics project is divided into weekly learning activities and objectives. In the first week, the industry representative presents the data analytics problem and the data available for solving the problem, and the students familiarise themselves with the problem and agree how they will communicate with the user during the project. In the second week, the students familiarise themselves with the user's data, identify and define the problem statement, explore the problem and data, and discuss with the user about questions related to the data. The goal of the second week is to understand what questions can be answered using the data provided by the user. The third week's learning activities include explorative analysis of data using Power BI, creating first visualisations, and discussing the visualisations with the user. The goal of the third week is to understand how the problem can be solved with the data at hand. The fourth week's learning activities include reframing and redefining the problem statement, cleansing and enhancing the data, creating new variables, and developing first metrics related to the solution. The goal of the fourth week is to understand what metrics are relevant for the user of the visualisation and data analytics solution. The learning activities of weeks five and six include appending and contextualising data from other data and information sources, creating views and dashboards for different user groups, and getting feedback from the users. Week seven is dedicated to preparing a presentation and material package for the customer, and week eight for pitching the solution and delivering the material.

As an example, a Biowaste company gave students the challenge of monitoring filling rate of biowaste containers. The students received data from the company that included number of apartments and the filling rates of housing associations. The company presented the challenge to the students during the first week of the data analytics project, and the student began to develop a solution to the challenge following design thinking process, and eight guiding speech balloons (Figure 1).

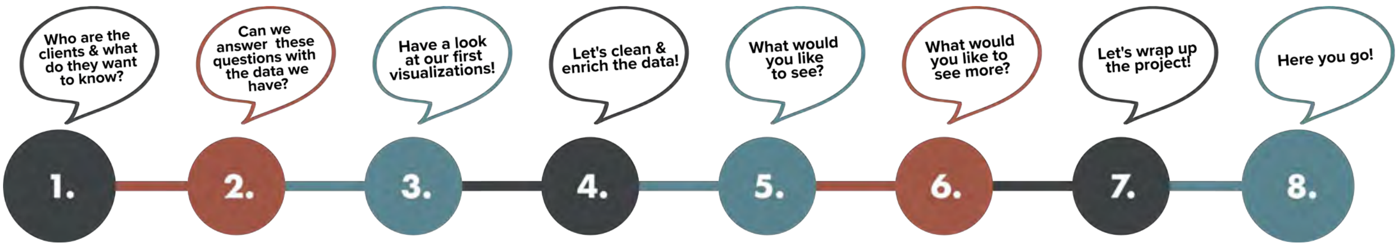

Figure 1. Speech balloons guiding the data analytics design process for the student projects.

In the second week, the students defined the problem worth solving for the customer and investigated whether they have the data necessary to develop a prototype visualization. The problem to be solved narrowed down to visualising filling rates of biowaste containers (0-110%) by housing associations, evaluating seasonal variability, and comparing filling rates by region and by number of housing units. In week three, the students ideated, developed a first prototype of the visualisation, and presented it to the customer to gain feedback for further development. The question of week four guided the students to clean and enrich their data to provide desirable visualisations for the customer. For instance, the colours and icons used to visualise biowaste containers were discussed and fine-tuned with the customer. Week five and six were about developing new iterations of the visualisations and testing it with the customer in weekly Team's meetings. In week 7, based on the feedback the students finalised the prototype and prepared a presentation for the customer to be delivered on week 8.

5 Empirical problem analysis

In the empirical problem analysis, the aim is to shed light on students' learning experiences and more specifically, to understand how the students can develop various general competences during the Design solution 1.0 described above.

5.1 Data collection and participants

The empirical problem analysis reported here is based on a set of data collected from Implementation 1.0 in spring 2020. All students in the implementation were invited to participate to answer an electronic questionnaire at the end of the course module. The students answered four open-ended questions:

1. What was the most useful or important thing you experienced or learnt during the study module? (Mikkonen et al., 2018)
2. Describe your experiences of industry collaboration during the study module. What did you learn about industry collaboration?
3. What factors contributed positively to your learning during the study module? How/why?
4. What factors contributed negatively to your learning during the study module? How/why?

In addition, the students had the possibility to give additional feedback in an open text field.

The students were studying on the information and communication technology, bioeconomy degree programme. One student did not give permission to use their responses for research purposes, so they were deleted from the data. The final sample size was N=25, which represents 83 per cent of the students on the course module. The students were first-year students, of whom 56 percent were female, 64 percent with a secondary degree and 36 per cent with a tertiary degree. This was the first time the students participated in a Design Factory implementation.

5.2 Data analysis

The students' responses to the open-ended questions were analysed through a theory-guided content analysis (Miles & Huberman, 1994; Schreier, 2012). As an analysis frame, we used the categories and subcategories empirically identified in another Design Factory context (Mikkonen et al., 2018). The categories were Interpersonal skills, Attitudes, Project development, and Project management. The subcategories are presented in Table 1. The unit of analysis was chosen to be a coherent set of ideas (Schreier, 2012). The total number of analysis units in the study was 104. The analysis was conducted using a person-oriented view in that the answers to all the questions by each student were analysed together; a student was coded into a subcategory if any of their responses included analysis units in that subcategory. Initially, the first author discussed the analysis frame with the second and the third authors to contextualise the categories in the Implementation 1.0 context, after which she coded the data independently. The student quotes reported in the next section were originally in Finnish and have been translated into English by the first author.

5.3 Results

The results from the qualitative coding are presented in Table 1. The distribution of the students' accounts was uneven between the main categories used in the analysis process; the students reported mostly on learning general competences that were categorised as Project development or Interpersonal skills. Note that most of the negative accounts in the Project management category are due the challenges cause by COVID-19. Next, we describe the central subcategories in more detail.

Table 1. The analysis categories (Mikkonen et al., 2018) and the number of students in each category. Positive and negative accounts refer to the identified positive and negative learning experiences and/or outcomes.

Category	Subcategory	Positive accounts	Negative accounts	Total
Interpersonal skills (29)	Teamwork overall	11	1	12
	Multidisciplinarity	-	-	-
	Importance of communication and how to do it effectively	10	5	15
	Multiculturality	-	-	-
	Networking and collaboration (e.g., industry and university staff)	2	-	2
Attitudes (2)	Knowing one's own role and abilities	1	-	1
	Confidence	-	-	-
	Curiosity, creativity, and constant learning	-	1	1
Product development (37)	Project development process and practices	4	1	5
	Prototyping and experimenting	-	-	-
	User-centred design and design thinking	6	-	6
	Defining and solving problems, working with uncertainty	3	-	3
	Domain-specific skills (e.g. technical, business)	21	2	23
Project management (21)	Managing and leading people	-	11	11
	Managing a development project and its tasks	4	6	10

The most common subcategory for positive learning experiences was Domain-specific skills in the Product development category (21 students). This category included students reports on learning about the data analytics tools. Often, the students named the software used. For example, a student stated:

> I learnt to use different data analytics tools in Office (Excel, PowerBI), which are certainly useful for the future. (ID11)

The students also described things they learnt about data analytics in general. This is demonstrated by the two following student quotes:

> [The most useful or important thing I learnt was] to overcome the challenges of data analytics. (ID2)
>
> I learnt to think about different ways data can be manipulated and all the problems data can be used to resolve. (ID17)

In the same Product development category, six students reported on learning in the User-centred design and design thinking subcategory. These accounts were mostly about "*thinking about issues from the client's perspective*" (ID5). Another student stated:

> [I learnt that] some clients can be very demanding, which is obviously only a good thing. The clients are the experts of their own product, for which we are supposed to help find solutions. (ID24)

The second most frequent category was Interpersonal skills. Students' positive accounts for learning Interpersonal skills derived mostly from the Teamwork overall (11 students) and Importance of communication (10 students) subcategories. The Teamwork overall subcategory included students' reports on teamwork and their teammates supporting their learning. For example, a student stated:

> The teamwork [supported my learning]. [Teammates] complemented my own set of skills and helped me when needed. (ID6)

To continue, another student stated:

> The team helped me a lot in learning: collaboration, working together, supporting one another. (ID4)

In the Importance of communication subcategory, the students mostly reflected on their general learning experiences of the university-industry collaboration. This is demonstrated by the three following student quotes:

> The [industry] collaboration went well, and I learnt that things go more smoothly if the other is easily reachable. (ID12)

> [I learnt that] industry collaboration is very interactive between the student and the company. Ideas are created on both sides. (ID5)

> I learnt to act in an appropriate but casual way. In industry collaboration, it is reasonable to operate on the client's terms and be flexible whenever possible. (ID7)

In addition to positive learning experiences, the students reported on issues that caused challenges for their learning of general competences. The challenges mostly derived from the Project management category and were to a great extent caused by the ongoing COVID-19 pandemic. For example, a student stated:

> Combining my own personal life and studying due to the crisis situation was a challenge [for learning]. (ID4)

In the few instances where negative accounts in the Project management category were not due to COVID-19, the students reported mathematics being *hard* or *just not that interesting*. Also, poorly functioning teamwork created stress for students:

> Our teamwork didn't function as well as I would have thought, and so I was a little stressed as I did a greater than expected share of the work. (ID22)

Besides Project management, students reported on challenges in the Interpersonal skills' Importance of communication and how to do it effectively subcategory. These challenges derived from various sources: from student's incomplete knowledge bases, the client's vague instructions, and poorly functioning teamwork. These are demonstrated by the following:

> The industry collaborations started at an early stage and the experience to analyse data came much later, so in the beginning you had no idea what you could and should so. It felt a bit like I was wasting [their] time because at first, I couldn't say or do anything. (ID6)

> From the client, I would have hoped for a description of the [...] data and more concrete expectations about the desired data analyses. In fact, the instruction was more like 'something should be done'. (ID14)

> In our team, communication with the client was very limited, so I feel like I didn't learn really anything about industry collaboration. We did attend meetings with the client, but we didn't participate that much in the discussions; instead we let the other team do most of the talking. (ID17)

5.4 Discussion of the empirical problem analysis

Most often, the students reported learning general competences included in the Product development category, with Domain-specific skills being the most frequent one. In contrast, in the former Design Factory students' retrospective reflections on general competences learnt during past Design Factory implementations, the Domain-specific skills subcategory was mentioned the least often (Mikkonen et al., 2018). This discrepancy may originate from various sources. First, unlike the other general competences in the analysis frame, the Product development category and in particular Domain-specific skills were stated in the course aims. Therefore, it can be considered a positive result that the students reported on developing general competences that are in line with the course aims. On the other hand, we acknowledge that the course aims require updating. Second, prior research acknowledges that recognising general competences is challenging for many students, even after graduation (Tuononen et al., 2019). Therefore, it is possible that the first-year students in this study had a limited understanding of professional practices and were not able to recognise all the competences they developed during the course. Also, the former Design Factory students in Mikkonen and colleagues' (Mikkonen et al., 2018) study were already in work; the competences they then recognised could be different from what they would have recognised right at the end of their Design Factory implementation (Mikkonen et al., 2018). However, as recognising these competences is important, we need to further reflect on how the Design Factory implementations could raise awareness of the general competences in students even more effectively.

In the study concerning the former Design Factory students (Mikkonen et al., 2018), the Interpersonal skills category was by far the most frequently reported. It was also central to the students in the present study, especially due to the frequent accounts related to the importance of communication and teamwork in general. The students in this study also reported negative accounts of Interpersonal skills, meaning that they recognised them as something they needed to put more effort into. In future implementations, this could be directly communicated to the students. Another topic related to the Interpersonal skills category is the COVID-19 pandemic, which started at the beginning of this implementation. How this influenced communication between team members, and between the team and the industry partner is not clear. However, communication is a multimodal thing and based on the students' responses, further attention is needed on all individual, team, and university-industry levels.

There are many subcategories with none or only a few students' accounts. These are competences that the former Design Factory students in Mikkonen and colleagues' study (Mikkonen et al., 2018) reported on developing during their Design Factory implementation. The learning of these competences needs to be addressed in future implementations. As discussed earlier, the course aims need to be revised from this perspective. The competences in the Attitudes category were most frequently reported as competences needed in the former Design Factory students' current work (Mikkonen et al., 2018). This must be addressed in future implementations, as developing competences in the Attitudes category would benefit the students later on in their careers – as demonstrated by the only student who reported on them (Attitudes/knowing one's own role and abilities):

> I became so familiar with remote working and the related tools that I believe that in the future, I can work for long periods relying only on them. It is a huge advantage in today's working life. (ID19)

As a final note on the empirical problem analysis, supporting the development of general competences in authentic university-industry collaboration seems to be challenging. First, the course aims were not fully aligned with the desired learning outcomes. This is relatively easy to change for future implementations. Second, the students might not have recognised all the general competences they developed during the implementation. This might be because recognising the competences is simply challenging (Tuononen et al., 2019; Tuononen & Lindblom-Ylänne, 2017). Also, as it is more efficient to learn general competences together with subject content (Schaeper, 2009), the students come across learning opportunities on multiple levels; perhaps they sometimes focus intensively on the subject content and not on the general competences. The multi-level learning objectives need to be stated clearly in the course aims but also communicated to students throughout the implementation. Third, to gain a more nuanced understanding of the development of general competences in the Design Factory context, the open-ended questions need to be supplemented with more versatile data collection methods, such as quantitative data and student interviews.

6 General discussion

In this section, we evaluate the first implementation, identify process-level challenges, and provide lessons learnt that will help refine the next iteration of the design solution. We also reflect overall on the DBR process and offer an extended theoretical perspective for supporting the development of general competences in university-industry collaboration.

Evaluation of the Implementation 1.0

When sharing and reflecting on the experiences from the implementation, we have gained a better understanding of the design process and the desired modifications which, in turn, have further clarified the relationships between the students, the companies, and the teachers. These reflections have also prompted us to consider further questions. To provide an example from the companies' perspective, some companies came to the implementation with a set of data and a challenge, and the data was discussed together with the students; however, some companies only delivered data and learnt exclusively what participating in this type of university-industry collaboration requires from them during the implementation. The challenge is that the companies need to be involved right from the beginning in order to transfer metadata and domain knowledge to the students. This will be considered in the next iteration cycles of the DBR process. However, this also prompts a new question to investigate: how can a university-industry collaboration model be created that can be easily implemented to readily engage any type of company? From a logistics perspective, this type of scalable model would be extremely useful.

From the students' perspective, it was also considered challenging when there was no introduction to the data or the process in general at the beginning – sometimes the students did not even receive sufficient information from the company during the process. This emphasises the vital role of communication in university-industry collaboration. We came to understand that the end-product itself is not sufficient for transferring the knowledge back to the company. Some students created a user manual for their data analytics product; we realised that for the students' products to be successful, this type of knowledge-transfer activity needs to be incorporated into all products developed during the iteration.

The students also requested more theory about participating in this type of university-industry collaboration – the process – and found that understanding the collaboration process is different from knowing how to use the tools. This reflects on the discussion of the empirical problem analysis: the learning objectives need to be extended to include learning objectives about the design process. Considering the learning objectives in general, it is necessary that the university-industry projects be linked to the learning objectives of the study module. Therefore, the assessment criteria cannot only consider whether the end product fits the company's needs, but it also needs to address the study module's learning objectives. Sometimes the companies wanted to change the direction or extend the goals of the product in the middle of the process. In our case, this happened after the companies realised the students' potential and skills with their data. Although this challenge has positive origins, in these instances it was important to reflect on the learning objectives of the study module, as they cannot be significantly altered in the middle of the implementation. This indicates that we were not able to cater for all the companies' requests. However, a scalable model that would engage the companies from the very beginning would prevent these issues from occurring.

Extending the theoretical approach of Design Factory pedagogy

The evaluation process of the DBR process has further clarified our understanding of the relationship between co-creation pedagogy and design thinking. This led us to introduce ourselves to the concept of *design-based education*. Design-based education is a further development of problem-based learning and competence-based education founded on the principles of sustainable education (Geitz & de Geus, 2019). One motivation for the development of design-based education has been to support the student to analyse the problem from several perspectives and to test and evaluate the prototype to determine whether the solution is really something that the customer wants (Geitz & de Geus, 2019). Essentially, design-based education is an iterative process of the design-based way of working and learning that includes six phases: 1) research the question; 2) define the core problem; 3) generate ideas; 4) design prototypes; 5) test prototypes; 6) research and improve (Geitz & de Geus, 2019). As design-based education shares its origins in competence-based education and problem solving with co-creation pedagogy, and incorporates the idea of design thinking, we see design-based education as a suitable theoretical framework for the Design Factory implementations.

However, we have extended the design-based education framework from three perspectives. The extended framework, design-based education in the co-creation pedagogy context, is presented in Figure 1. First, we have supplemented the design-based education model by Geitz and de Geus (Geitz & de Geus, 2019) with the notion of resources. A sole business challenge or brief is not enough – a team cannot implement a data analytics solution in a company if the company does not provide the team with sufficient resources, such as the data and domain knowledge, in tandem with the challenge. Therefore, resources were added to the professional domain part of the figure. Second, we have aligned design-based education with the co-creation pedagogy. This serves the purpose of emphasising that the problems students solve are not predetermined but the problem space is discussed, negotiated and defined within the university-industry collaboration. This indicates that the module's learning objectives and the design problem needs to be aligned, as well as the module evaluation and the design product. This embodies the authentic integration of the educational and professional domains in the Design Factory context. Thirdly, we have expanded the activity with a more detailed description of design thinking process. Design thinking process includes most often five or six phases (Thoring & Müller, 2011; Tu et al., 2018; von Thienen et al., 2017), but is should not be viewed as a linear process, but as process that has feedback loops (Thoring & Müller, 2011) that lead to iteration of one or more phases until satisfactory results are reached. In Table 2, we describe how we see design-based education in the co-creation contexts in the Implementation 1.0.

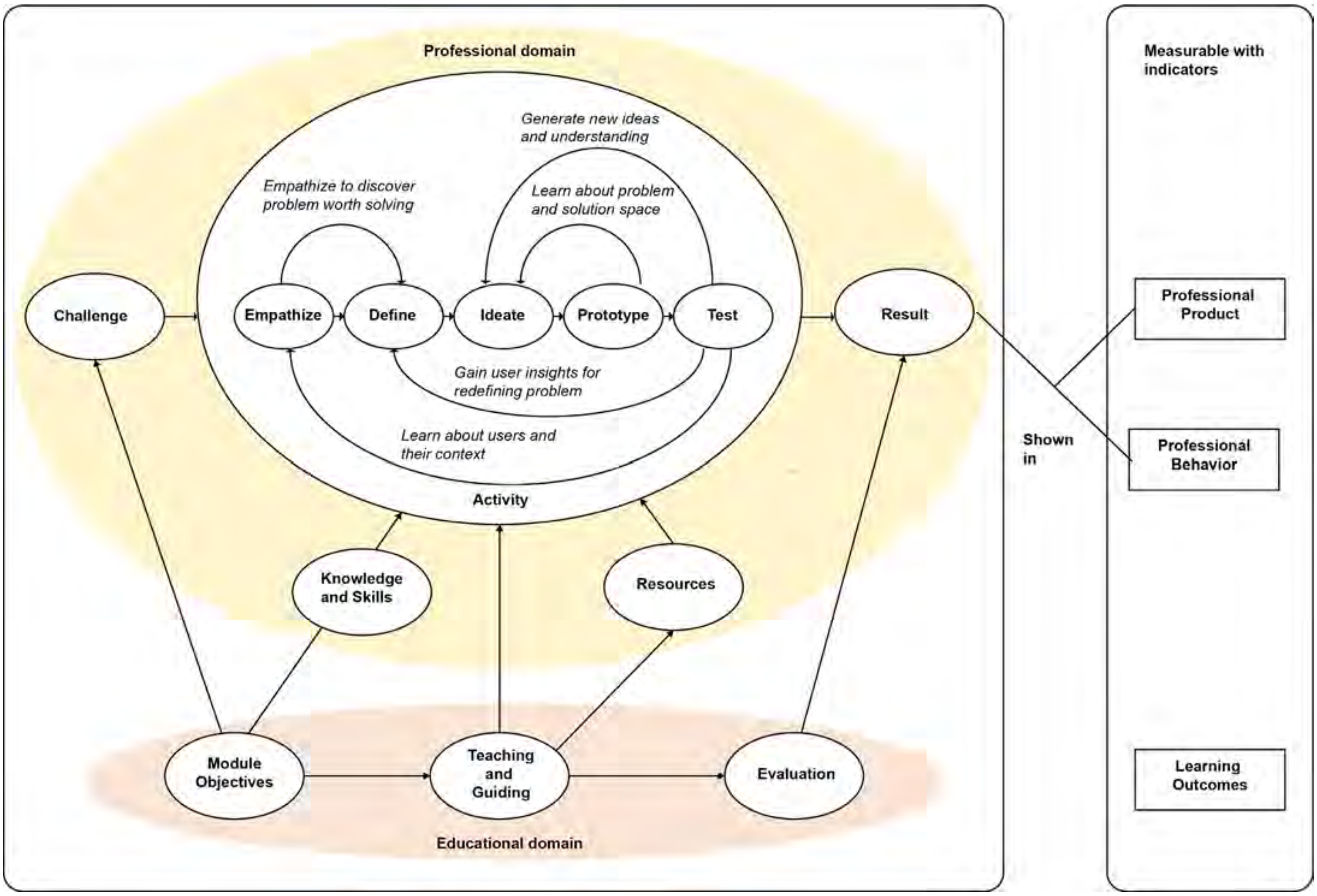

Figure 2. Design-based education (professional domain) in the co-creation pedagogy context (educational domain) (Geitz & de Geus, 2019) as the proposed theoretical framework for Design Factory implementations.

Table 2. Description of the co-created design-based education process in the implementation.

Design element	Implementation
Challenge	Company introduces a business challenge that can be potentially solved with data analytics.
Activity	Following the five steps of the design thinking process (Jussila et al., 2020), students design a data analytics solution for the company in weekly interaction with the company.
Result	Presentation and a tested prototype of data analytics solution for the company.
Knowledge and Skills	(Knowledge) Students understand how data analytics can be applied in bioeconomy engineering. (Skills) Students can conduct user research, define a problem, ideate a solution, analyse, model and visualise data, create a prototype of data analytics solution, conduct user testing, and manage a data analytics project for customer.

Resources	Company provides data, business understanding, and user experience needed to design a solution for data analytics problem. Teachers provide resources such as data analytics tools and learning material to support project work.
Module Objectives	Students learn the basics of data analytics and upon completion of the module they understand the possibilities of data analytics in bioeconomy engineering.
Teaching and Guiding	For the duration of the project, teachers provide weekly guidance, and students interact with the company once a week.
Evaluation	Resulting solutions were evaluated on a scale of 0–5, according to how well it solves user needs and the company's business problem.
Professional Product	The data analytics solution is designed so that it can be implemented in the company.
Professional Behaviour	Students can professionally communicate with the company and present their findings.
Learning Outcomes	Students are able to independently complete even the most demanding assignments in the module and know how to apply the acquired knowledge in practice.

Concluding remarks

In the next iteration cycles, the connections between design-based education and co-creation pedagogy – the professional and the educational domains – need to be investigated and reflected on further. However, extending design-based education to the context of co-creation pedagogy conceptualises the authentic course-level university-industry collaboration process. This addresses the need to conceptualise general competences and investigate their development in a disciplinary context (Biggs & Tang, 2011; Chan & Fong, 2018; Jones, 2009; OECD, 2012). Furthermore, the new theoretical framework for Design Factory implementations (i.e., university-industry collaboration) contributes to the ongoing semantic and conceptual work in defining the general competences even more relevant in the future (OECD, 2018).

There has been a lack of clear articulation of the Design Factory pedagogical approach. The results support the members of the Design Factory Global Network to articulate the pedagogical approach used in their everyday practices and facilitates dissemination and visibility of the Design Factory approach. More generally, the results of the present study support anybody interested in design approach and university-industry collaboration to formulate more appropriate learning objectives and to communicate them and the design process more effectively to both students and companies. We hypothesise that with this type of clarification of the pedagogical approach, it will be possible to further support students to develop their general competences.

In the present study, we considered only the students' perspectives and the teachers' retrospective reflections. In the future, it would be valuable to collect richer data, including the companies' perspectives. Also, future implementations will be realised in interdisciplinary teams, thus emphasising the role of general competences, and adding new and interesting possibilities for research inquiry.

References

Anderson, T., & Shattuck, J. (2012). Design-based research: A decade of progress in education research? *Educational Researcher*, *41*(1), 16–25. https://doi.org/10.3102%2F0013189X11428813

Barab, S., & Squire, K. (2004). Design-based research: Putting a stake in the ground. *Journal of the Learning Sciences*, *13*(1), 1–14. https://doi.org/10.1207/s15327809jls1301_1

Barrie, S., Hughes, C., & Smith, C. (2009). *The national graduate attributes project: Integration and assessment of graduate attributes in curriculum*. Australian Learning and Teaching Council.

Biemans, H., Nieuwenhuis, L., Poell, R., Mulder, M., & Wesselink, R. (2004). Competence-based VET in the Netherlands: Background and pitfalls. *Journal of Vocational Education and Training*, *56*(4), 523–538. https://doi.org/10.1080/13636820400200268

Biggs, J. (1994). Student learning research and theory: Where do we currently stand? In G. Gibbs (Ed.), *Improving student learning: Using research to improve student learning* (pp. 1–19). Oxford Centre for Staff Development.

Biggs, J., & Tang, C. (2011). *Teaching for quality learning at university* (4th ed.). McGraw-Hill Education.

Björklund, T. A., Keipi, T., Celik, S., & Ekman, K. (2019). Learning across silos: Design Factories as hubs for co-creation. *European Journal of Education*, *54*(4), 552–565. https://doi.org/10.1111/ejed.12372

Brown, A. L. (1992). Design experiments: Theoretical and methodological challenges in creating complex interventions in classroom settings. *Journal of the Learning Sciences*, *2*(2), 141–178. https://doi.org/10.1207/s15327809jls0202_2

Caballero, G., Álvarez-González, P., & López-Miguens, M. J. (2020). How to promote the employability capital of university students? Developing and validating scales. *Studies in Higher Education*, *45*(12), 2634–2652. https://doi.org/10.1080/03075079.2020.1807494

Chan, C. K. Y., & Fong, E. T. Y. (2018). Disciplinary differences and implications for the development of generic skills: A study of engineering and business students' perceptions of generic skills. *European Journal of Engineering Education*, *43*(6), 927–949. https://doi.org/10.1080/03043797.2018.1462766

Collins, A., Joseph, D., & Bielaczyc, K. (2004). Design research: Theoretical and methodological issues. *Journal of the Learning Sciences*, *13*(1), 15–42. https://doi.org/10.1207/s15327809jls1301_2

diSessa, A. A., & Cobb, P. (2004). Ontological innovation and the role of theory in design experiments. *Journal of the Learning Sciences*, *13*(1), 77–103. https://doi.org/10.1207/s15327809jls1301_4

Edelson, D. C. (2002). Design research: What we learn when we engage in design. *Journal of the Learning Sciences*, *11*(1), 105–121. https://doi.org/10.1207/S15327809JLS1101_4

Freudenberg, B., Brimble, M., & Cameron, C. (2011). WIL and generic skill development: The development of business students' generic skills through work-integrated learning. *Asia-Pacific Journal of Cooperative Education*, *12*(2), 79–93.

From UAS to Career. (2020). *UAS career monitoring survey—Results of the graduates of 2015*. https://amk-uraseuranta.turkuamk.fi/en/results/

Geitz, G., & de Geus, J. (2019). Design-based education, sustainable teaching, and learning. *Cogent Education*, *6*(1), 1647919. https://doi.org/10.1080/2331186X.2019.1647919

Greenbank, P., Hepworth, S., & Mercer, J. (2009). Term-time employment and the student experience. *Education + Training*, *51*(1), 43–55. https://doi.org/10.1108/00400910910931823

Hannula, J. (2019). *Kehittämistutkimus: Matematiikan aineenopettajaopiskelijoiden matemaattisen ja pedagogisen sisältötiedon edistäminen ongelmalähtöisessä oppimisessa [Design-based research: Supporting the development of pre-service mathematics teachers' mathematical and pedagogical content knowledge through problem-based learning]* [Doctoral dissertation, University of Helsinki]. https://helda.helsinki.fi/handle/10138/303396

Healy, M., Hammer, S., & McIlveen, P. (2020). Mapping graduate employability and career development in higher education research: A citation network analysis. *Studies in Higher Education*, 1–13. https://doi.org/10.1080/03075079.2020.1804851

Jones, A. (2009). Redisciplining generic attributes: The disciplinary context in focus. *Studies in Higher Education*, *34*(1), 85–100. https://doi.org/10.1080/03075070802602018

Jussila, J., Raitanen, J., Partanen, A., Tuomela, V., Siipola, V., & Kunnari, I. (2020). Rapid product development in university-industry collaboration: Case study of a Smart Design Project. *Technology Innovation Management Review*, *10*(3), 49–59. https://doi.org/10.22215/timreview/1336

Juuti, K., & Lavonen, J. (2006). Design-based research in science education: One step towards methodology. *Nordic Studies in Science Education*, *2*(2), 54–68. https://doi.org/10.5617/nordina.424

Kavanagh, M. H., & Drennan, L. (2008). What skills and attributes does an accounting graduate need? Evidence from student perceptions and employer expectations. *Accounting & Finance*, *48*(2), 279–300. https://doi.org/10.1111/j.1467-629X.2007.00245.x

Kember, D., & Leung, D. Y. P. (2005). The influence of the teaching and learning environment on the development of generic capabilities needed for a knowledge-based society. *Learning Environments Research*, *8*(3), 245. https://doi.org/10.1007/s10984-005-1566-5

Kunnari, I., Jussila, J., Tuomela, V., & Raitanen, J. (2019). Co-creation pedagogy from cSchool towards HAMK Design Factory. *HAMK Unlimited Journal*. https://unlimited.hamk.fi/in-english/co-creation-pedagogy/

Kunttu, L. (2017). Educational involvement in innovative university-industry collaboration. *Technology Innovation Management Review*, *7*(12), 14–22. https://doi.org/10.22215/timreview/1124

Kunttu, L., & Neuvo, Y. (2019). Balancing learning and knowledge protection in university-industry collaborations. *The Learning Organization*, *26*(2), 190–204. https://doi.org/10.1108/TLO-06-2018-0103

Mavromaras, K., McGuinness, S., O'Leary, N., Sloane, P., & Wei, Z. (2013). Job mismatches and labour market outcomes: Panel evidence on university graduates. *Economic Record*, *89*(286), 382–395. https://doi.org/10.1111/1475-4932.12054

Mikkonen, M., Tuulos, T., & Björklund, T. (2018). Perceived long term value of industry project-based design courses: Alumni reflections from two decades of the Product Development Project. In P. Ekströmer, S. Schütte, & J. Ölvander (Eds.), *DS 91: Proceedings of NordDesign 2018*. Linköping University.

Miles, M. B., & Huberman, A. M. (1994). *Qualitative data analysis: An expanded sourcebook* (2nd ed.). SAGE Publications.

OECD. (2012). *Assessment of higher education learning outcomes, AHELO feasibility study report Volume 1, Design and implementation*. http://www.oecd.org/education/skills-beyond-school/AHELOFSReportVolume1.pdf

OECD. (2018). *The future of education and skills—Education 2030. OECD Position Paper*. https://www.oecd.org/education/2030-project/contact/E2030_Position_Paper_(05.04.2018).pdf

Pernaa, J. (2013). Kehittämistutkimus tutkimusmenetelmänä [Design-based research as a research methodology]. In J. Pernaa (Ed.), *Kehittämistutkimus opetusalalla [Design-based research in education]* (pp. 9–26). PS-Kustannus.

Plattner, H. (Ed.). (2010). *Design thinking: Understand – improve – apply*. Springer.

Projectbureau Competent HTNO. (2000). *Gids voor het beschrijven van de landelijke kwalificaties in het HTNO [Guide to describe the national qualifications in the HTNO]*. Competent HTNO.

Schaeper, H. (2009). Development of competencies and teaching-learning arrangements in higher education: Findings from Germany. *Studies in Higher Education*, *34*(6), 677–697. https://doi.org/10.1080/03075070802669207

Schreier, M. (2012). *Qualitative content analysis in practice*. SAGE.

Strijbos, J., Engels, N., & Struyven, K. (2015). Criteria and standards of generic competences at bachelor degree level: A review study. *Educational Research Review*, *14*, 18–32. https://doi.org/10.1016/j.edurev.2015.01.001

Thoring, K., & Müller, R. M. (2011). Understanding design thinking: A process model based on method engineering. In A. Kovacevic, W. Ion, C. McMahon, L. Buck, & P. Hogarth (Eds.), *DS 69: Proceedings of E&PDE 2011, the 13th International Conference on Engineering and Product Design Education* (pp. 493–498). Design Society.

Tu, J.-C., Liu, L.-X., & Wu, K.-Y. (2018). Study on the learning effectiveness of Stanford Design Thinking in integrated design education. *Sustainability*, *10*(8), 2649. https://doi.org/10.3390/su10082649

Tuononen, T., & Lindblom-Ylänne, S. (2017). The transition from university to working life: An exploration of graduates' perceptions of their academic competences. In E. Kyndt, V. Donche, K. Trigwell, & S. Lindblom-Ylänne (Eds.), *Higher Education Transitions: Theory and Research*. Routledge.

Tuononen, T., Parpala, A., & Lindblom-Ylänne, S. (2019). Graduates' evaluations of usefulness of university education, and early career success – a longitudinal study of the transition to working life. *Assessment & Evaluation in Higher Education*, *44*(4), 581–595. https://doi.org/10.1080/02602938.2018.1524000

Tuononen, T., Parpala, A., & Lindblom-Ylänne, S. (2020). Complex interrelations between academic competences and students' approaches to learning – mixed-methods study.

Journal of Further and Higher Education, *44*(8), 1080–1097. https://doi.org/10.1080/0309877X.2019.1648776

Tynjälä, P., Virtanen, A., Klemola, U., Kostiainen, E., & Rasku-Puttonen, H. (2016). Developing social competence and other generic skills in teacher education: Applying the model of integrative pedagogy. *European Journal of Teacher Education*, *39*(3), 368–387. https://doi.org/10.1080/02619768.2016.1171314

Ursin, J., Hyytinen, H., & Silvennoinen, K. (Eds.). (2021). *Assessment of undergraduate students' generic skills in Finland: Findings of the Kappas! Project* (Vol. 31). Ministry of Education and Culture. http://urn.fi/URN:ISBN:978-952-263-892-2

von Thienen, J., Royalty, A., & Meinel, C. (2017). Design thinking in higher education: How students become dedicated creative problem solvers. In C. Zhou (Ed.), *Handbook of research on creative problem-solving skill development in higher education*. IGI Global. https://doi.org/10.4018/978-1-5225-0643-0