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Validating an individual innovation competence assessment tool for university-industry collaboration

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Abstract

University–industry collaboration produces networks that may be capable of innovations, such as novel products and services. The collaboration projects also need to benefit student learning, yet teachers have little clarity in innovation competence development. Individual innovation competence is a set of personal characteristics, knowledge, skills and attitudes that are connected to create concretised and implemented novelties via collaboration in complex innovation processes. The paper reports on the findings from the development and validation of an individual innovation competence assessment tool. The aim is to determine which individual innovation competences are significant in university–industry collaboration and which of these competences are sensitive to educational interventions. The study used a three-phase method involving development of the questionnaire items, validation in teacher and student panels, and pilot pre- and post-survey study. All seven domains of individual innovation competences were significant and sensitive to educational intervention; namely, a multidisciplinary innovation project conducted with industry. The most responsive competence domains regarding change were concretisation and implementation planning skills, and project management skills. The paper concludes with application opportunities for the tool and recommendations for further research.

Introduction

This paper reports the findings of the development and validation of a competence assessment tool that can be used to define individual innovation competence. University–industry innovation collaboration produces open research, development and innovation (RDI) networks that may be capable of generating innovations, such as novel products and services (Ankrah and Al-Tabbaa, 2015; Mäkimattila et al., 2015; Rantala and Ukko, 2018; Slotte and Tynjälä, 2003). Collaboration projects also need to benefit learning, and not only the organisations looking for innovations. This collaboration may promote participant innovativeness, which can be referred to as *individual innovation competence* (IIC; Hero et al., 2017). However, a fundamental issue in innovation and entrepreneurship education is the hidden nature of the foundations that underpin its delivery and assessment (Fayolle et al., 2016; Neck and Corbett, 2018; Seikkula-Leino et al., 2010).

Previous research has found a need to understand and develop self-report assessment tools that can be integrated into innovation pedagogy (e.g. Keinänen et al., 2018; Nielsen 2015). The aim of this study was to define, develop and validate an individual innovation competence scale for the higher education–industry collaboration context. An IIC scale and an assessment tool based on the scale is needed as authentic university–industry innovation processes have very limited clarity in terms of teachers being able to assess projects and competence development on the individual student level (Helle et al., 2006). Thus, the pedagogy is very hard to improve.

According to Mitchelmore & Rowney (2010), if competence frameworks are to be used it is important to be able to measure competencies before and after any intervention and to be able to prioritize the ones that would benefit from development for specific individuals. Self-assessment tools can be used to determine the respondents' situation both before and after an

intervention or work project to allow for insights to be gained into the experience during the intervention (cf. Andrade, 2019). In industry project work context it can be used to discover employee competence development during a project. In higher education, pre–post- and post–pre-assessment tools can be used to evaluate the impact of an instruction; that is, a course, program, or workshop (Heibert et al., 2011). Teachers involved in innovation and entrepreneurship programs can use the tools to determine the impact of their project-based pedagogy and teaching. By promoting rigour in the development of the scale in authentic innovation project context, it is also possible to put the scale to wider use with industry partners and develop innovation competence in companies and public organisations.

Towards individual innovation competence

According to Mulder (2012), Mulder and Gulikers (2011) and Sturing et al. (2011), competence is defined to integrate knowledge, skills and attitudes as an integrated entity that manifests itself in performance in a specific context and in concrete, authentic tasks. The competence needed in innovation processes can refer to knowledge, skills and attitudes (see Zhuang, Williamson, & Carter, 1999), but the influence of individual characteristics also seems to be significant (Da Silva and Davis, 2011). Mulder (2012) has distinguished three perspectives for competence: behavioural functionalism, integrated occupationalism and situated professionalism. In this study, we follow Mulder (2012) in his definition of competence as situated professionalism, as it means that competence only holds meaning in a specific context in which professionals interact with each other.

The two different terms, competence and competency are intertwined but distinct. Competence is the evaluation of performance in a specific activity, whereas competency is a class of things that can be used to characterise individual abilities and their behaviours (see Michelmore and Rowney 2010). Competencies are learnable and attainable through

experience, learning and coaching (Volery, Mueller and von Siemens, 2015). Competence shows as behaviour in an activity in an authentic context and it should have an intention related to action (Spencer and Spencer, 1993).

Differences between innovation and entrepreneurial competences

Innovation and entrepreneurship competences seem to intertwine and overlap. Entrepreneurship competence has been defined as a part of innovation competence, and vice versa. (Bjornali and Støren, 2012; Cerinšek and Dolinšek, 2009; Chell and Athayde, 2011; Edwards-Schachter et al., 2015; Gundry et al., 2014; Kasule et al., 2015; Santandreu-Mascarell et al., 2013; Waychal et al., 2011). According to Waychal et al. (2011), entrepreneurial abilities (along with creativity and achievement orientation) are factors of innovation as a competence. According to Gundry et al. (2014), innovation (in addition to risk-taking and proactive behaviour) is a central dimension of entrepreneurship. Proactive entrepreneurs who adopt a strategic orientation that permits flexibility and responsiveness are more likely to innovate. Entrepreneurial competence relates to actions where a business is started, transformed (Mitchelmore and Rowley, 2011) and grown (Bird 1995). Entrepreneurial competencies have been defined in many ways, e.g. risk-taking, positive thinking, vision, intuitive decision making, creative problem-solving, managing interdependency, tolerating ambiguity and innovation (Bissola, Imperatori and Biffi, 2017). In higher education, the ultimate purpose of entrepreneurship education is to help potential entrepreneurs launch new ventures and understand the consequences of their decisions, whereas the purpose of innovation programs is to enhance the innovative performance of individuals and organisations (Maritz and Brown, 2013; Maritz and Donovan, 2015). However, individual innovation competence as a part of entrepreneurship competence often lacks a clear definition and differs from entrepreneurial competence.

Innovation competence manifests itself in context

There are several meanings for the term *innovation competence* according to the context in which the term is used. Most of the research has examined the innovation competence of organisations (e.g. Kodama and Shibata, 2014; Wang, 2014), the country-, region- or area-level innovation competences of organisations (e.g. DiPietro, 2009), the innovativeness of non-human things, such as innovative software (e.g. Lim et al., 2011), or innovativeness as consumer technology adoption (e.g. Manning et al., 1995) but not creating that technology or product. This study focuses on the individual-level human competence related to the development of innovations; that is, the creation of innovations as the collaborative work of several individual people.

Competence manifests itself in context and tasks (Mulder 2012; Sturing et al. 2011). More specifically, competence is measured through behaviour – as an individual's ability to act in an authentic situation. Innovation development, the context where IIC is needed, relates to actions where concretised and implemented novelties are created via collaboration in complex innovation processes. These outcomes are understood as novelties that are made concrete, useful and implemented to convey value (mainly following Peschl et al., 2014; Quintane et al., 2011; Sawyer, 2006, 2009). They can take such forms as new services, products, processes, marketing and organisational innovations (Oslo Manual, 2005).

Innovation development is often associated with teams of diverse individuals and networked multi-professional collaborations (e.g. Nandan and London, 2013; Van Der Vegt and Bunderson, 2005). The motivation for such organisation often springs from the need to solve complex problems that benefit from diverse perspectives and the needed versatile talent (Kurtzberg, 2005; Van der Vegt and Janssen, 2003). The ambitious goal of producing an

innovation requires multidisciplinary collaboration to produce a large number of high-quality original ideas and to develop the competence needed in such versatile and multistage work. The multidisciplinary composition of teams in innovation networks allows for the complementarity of competence (Miettinen and Lehenkari, 2016).

Individual innovation competence

Individual innovation competence is understood as a set of personal characteristics, knowledge, skills (or abilities) and attitudes that are connected to create concretised and implemented novelties via collaboration in complex innovation processes. Previous empirical research on innovation competence development in university–industry innovation projects exists primarily with respect to single-discipline higher education contexts (e.g. Gilbert, 2011; Keinänen and Oksanen, 2017; Liebenberg and Mathews, 2012; West and Hanafin, 2011). Only a few studies have specifically addressed the multidisciplinary learning that novel innovations seem to require. (e.g. Heikkinen and Isomöttönen, 2015; Johnsen, 2016; Muukkonen et al., 2013). There are several validated innovation competence assessment scales in the research literature. E.g. There are scales concentrating on domains such as creative problem solving, systems thinking, goal orientation, teamwork and networking (Keinänen et al., 2018), or on creativity, critical thinking, initiative, teamwork and networking (Keinänen and Butter, 2018; see also Edwards-Schachter et al., 2015), but not on e.g. concretisation and implementation requirements included in many innovation definitions (e.g. Peschl et al., 2014; Quintane et al. 2011).

According to a recent systematic review (Hero, Lindfors and Taatila, 2017), and its complementary empirical studies (Hero, 2017; Hero and Lindfors, 2019), those factors are ***personal characteristics*** such as self-esteem (e.g. Avvisati et al., 2013; Santandreu-Mascarell

et al., 2013), self-management (e.g. Bjornali and Støren, 2012; Chatenier et al., 2010), achievement orientation (e.g. Mathisen et al. 2008; Montani et al., 2014), motivation and engagement (e.g. Chatenier et al., 2010; Chell and Althayde, 2011; Edwards-Sachter et. al., 2015; Montani et al., 2014; Waychal et al., 2011), flexibility (e.g. Nielsen, 2015) and responsibility (Hero and Lindfors 2019); ***skills*** such as future orientation (Montani et al., 2014; Vila et al., 2014; Waychal et al., 2011), creative thinking skills (e.g. Chatenier et al., 2010; Edwards-Schachter et. al., 2015), social skills such as networking, collaboration and communication skills (e.g. Avvisati et al., 2013; Bjornali and Støren, 2012; Santandreu-Mascarell et al., 2013), development project management skills (e.g. Chatenier et al., 2010; Hero and Lindfors, 2019; Nielsen, 2015), implementation planning skills such as making, productisation, sales, marketing and entrepreneurship planning skills (Arvanitis and Stucki, 2012; Bruton, 2011; Hero, 2017, 2019; Hero and Lindfors, 2019); and ***knowledge*** such as one's own and other's discipline content knowledge (e.g. Avvisati et al., 2013; Bjornali and Støren, 2012).

Similar to other competences, innovation competence can be learned and developed (Bruton, 2011; Peschl et al., 2014). The progress or lack of progress towards such competences needs to be discovered to be able to adjust teaching to match with industry needs, student-experienced competence gaps and with the authentic contexts in which learning projects are conducted.

Aim, materials and methods

This study defines, develops and validates an IIC scale for the higher education–industry collaboration context. It set to explore which individual innovation competencies are significant in university–industry collaboration and which of these competencies are sensitive to authentic project-based educational intervention. Based on discovered need (Seikkula-

Leino et al., 2010), the aim was to develop an IIC scale to be used as a self-assessment tool within an authentic project collaboration context for innovation. In higher education, self-rating questionnaires are applicable because they are relatively cheap and easy to administer (Braun et al., 2012). The research questions are: What individual innovation competences are significant in a university–industry collaboration? Which of these competences are sensitive to educational interventions in a multidisciplinary context? These questions are important to be answered as today in higher education, collaboration projects and project-based pedagogies serve the opportunity to be more practical and focus on developing concrete outcomes and professional competences. The teaching staff are involved in an advisory, rather than in an authoritarian role. (Helle et al., 2006) These pedagogical processes are often authentic open innovation projects that may result in real multidisciplinary RDI networks being formed, producing incremental or even radical new solutions and promoting student entrepreneurship. Thus, the multidisciplinary innovation pedagogy in higher education institutions promotes competence for students and new concrete products, services or other authentic, practical and usable solutions for industry or society (Heikkinen and Isomöttönen, 2015; Ness and Riese, 2015).

We used a three-phase method to develop the IIC Scale, as summarised in Figure 1.

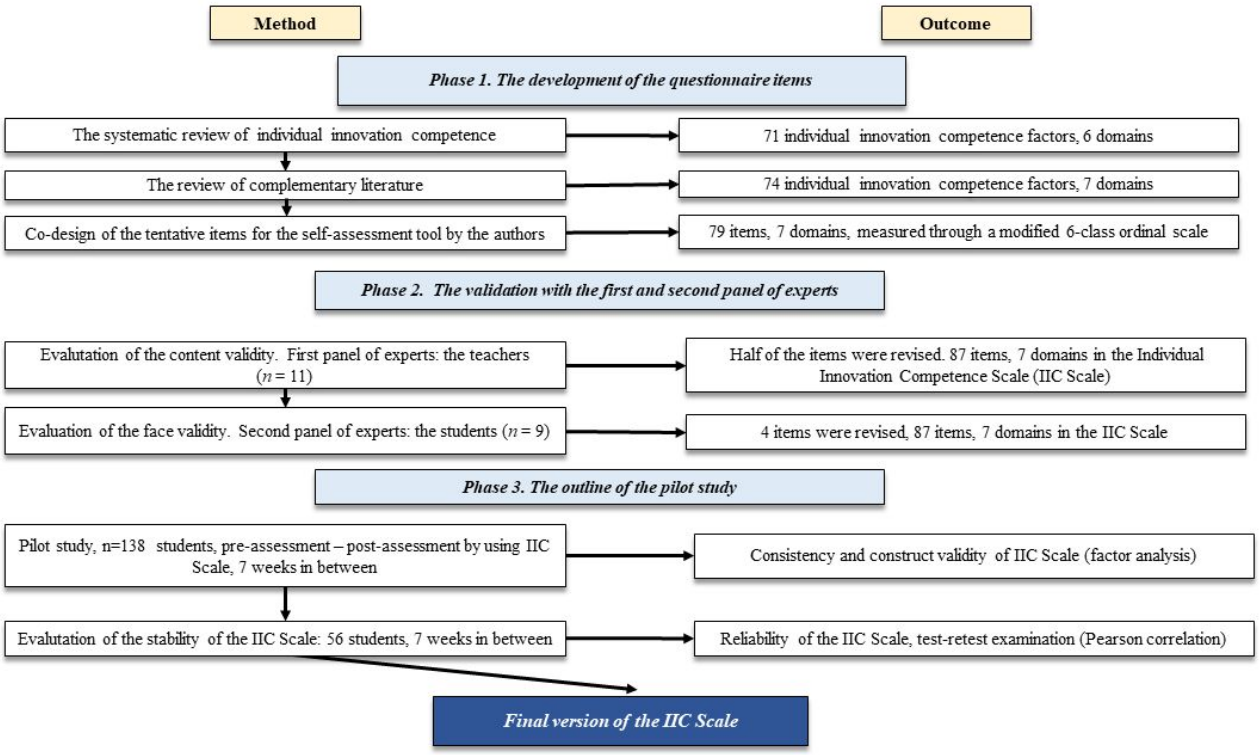

Figure 1. Methods and outcomes in the development phases of the IIC Scale.

Each of the three phases consisted of research activities and their outcomes that developed the scale step-by-step towards a survey questionnaire that could later be used to unveil the impact of educational interventions on student innovation competence development.

The development of the questionnaire items

Initially, we used the findings from a systematic literature review by Hero et al. (2017) as well as from its complementary empirical studies (Figure 2; Hero, 2017, 2019; Hero and Lindfors, 2019) to uncover the factors that are linked with individual innovation competence. The benefit of systematic review method as a base study here is its opportunity to advance rigour in material collection by using strict inclusion criteria and bias assessment; and that it has been able to report findings in a transparent way (Higgins, 2008; Petticrew and Roberts, 2006).

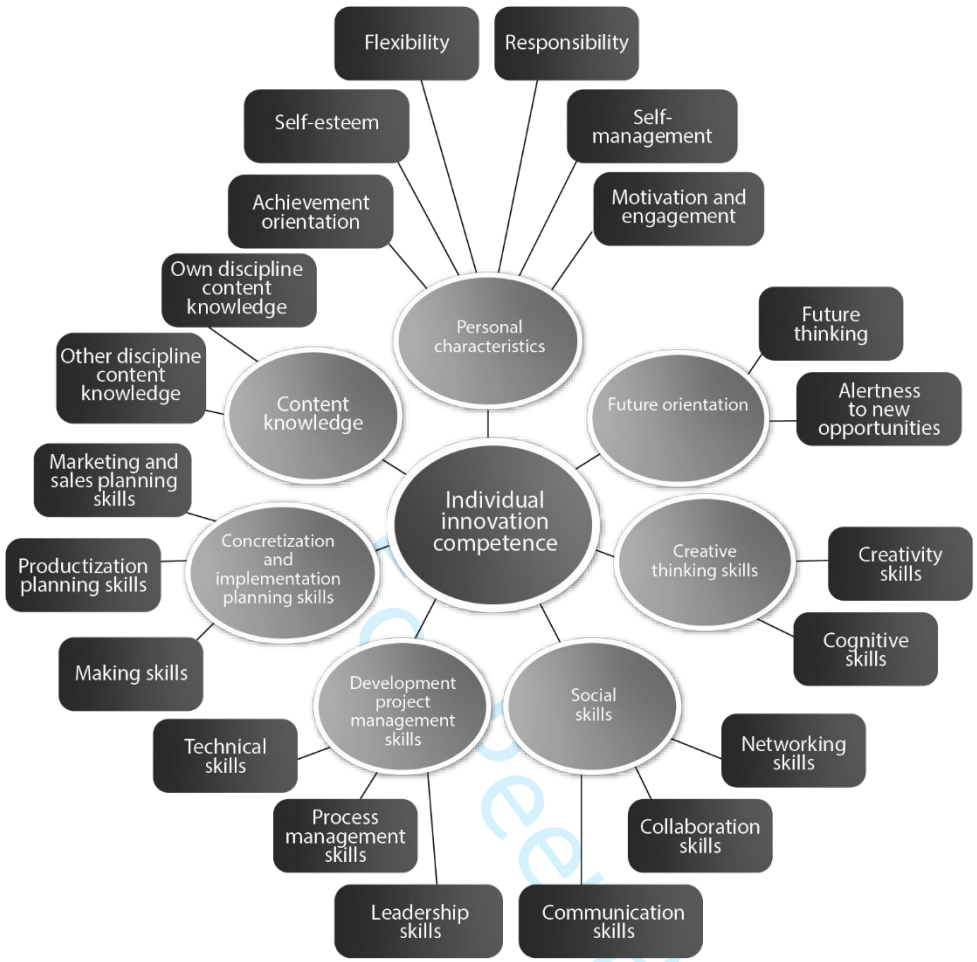

Figure 2. Sub-categories and domains of individual innovation competence identified for the development of statements (Hero et al., 2017; Hero, 2017; Hero and Lindfors, 2019).

Altogether, 74 IIC factors were identified and further categorised into 21 sub-categories and further to seven domains.

Similar to the instrument development process reported by Nilsson and colleagues (2014), we transformed the factors into statements, which eventually became items in the IIC Scale. The items described the respondents' behaviours rather than their characteristics. Specifically, the items were operationalised statements of the students' self-assessed ability to act in an authentic collaborative and networked innovation development process. The items were

designed by following the recommendations of Braun et al. (2012). Vague terms, retrospective estimation and double-barrelled questions were avoided. Double-barreled questions were split into two questions. Therefore, by the end of Phase I, there were 79 items in the IIC Scale.

The validation with the first and second panel

In the second phase, as suggested by Braun et al. (2012), we invited a panel of teachers experienced in multidisciplinary innovation project tutoring to comment on the questionnaire items to confirm the content and construct validity of our scale. Of the 33 potential participants, 11 participated in a workshop. Approximately half of the items were further developed. Most of the problems concerned wording. For example, in the 'Concretisation and implementation planning skills' category, regarding esthetical and psychomotor skills, the item 'I know how to use my psychomotor skills that are required in the realisation of a new concrete product' was changed to 'I know how to use my crafting skills that are required in the realisation of a new concrete product.' *Psychomotor* was considered an unknown term to the target group.

The common denominators for innovation development conditions were discussed, and there were several statements where the conditions had to be described in more detail to delimit a context to the behaviour in question: 'I know how to use my sense of beauty' was continued with '... in the realisation of a quality product' and 'I can work actively to add value to my team to achieve our goals' and 'I am capable of leading a team.' Several of the problems concerned the double-barrel issue (Braun et al., 2012). For example, 'Openness to experiences' was initially formulated as 'I am curious and open to new experiences', but was sharpened up by the panel so that it only expressed one adjective. Eight items had to be added

based on the problems in the items described above. After this phase, the IIC Scale comprised 87 items.

To ensure face validity, a student panel was also invited to test the tool. A group of undergraduate students who had recently completed innovation studies were sent an email invitation to participate in the panel. Of the 172 potential students, nine participated by filling in the survey consisting of the 87 items. An extra column was added next to the rating scale to allow for open comments. Their feedback resulted in minor language modifications to four items. Finally, the IIC Scale consisted of 87 items in seven domains relating to *Personal characteristics* (17 items), *Future orientation* (10 items), *Creative thinking skills* (13 items), *Social skills* (14 items), *Project management skills* (21 items), *Content knowledge* (2 items) and *Concretisation and implementation planning skills* (10 items).

The measurement was carried out using a 6-point ordinal Likert-type scale (0 = *cannot say*, 1 = *not at all*, 2 = *weakly*, 3 = *moderately*, 4 = *very well*, 5 = *excellent*). In addition to the survey, we assessed age, gender, degree programme, language of instruction, study year and the participants' understanding of what the term *innovation* meant. This background information was examined through open questions and nominal scale variables, when appropriate.

The outline of the pilot study

Finally, the IIC Scale was pilot tested. The pilot study aimed at ensuring the consistency and reliability of the IIC Scale (Braun et al., 2012). Furthermore, the findings of the pilot study addressed the aim of discovering which individual innovation competences are significant in

a university–industry collaboration and which of these competences are sensitive to innovation project-types of educational interventions.

The self-assessment tool was pilot tested in a multidisciplinary innovation pedagogy context in one university of applied sciences in Finland. This pedagogical intervention was a 7-week university–industry MINNO® Innovation Project implemented at Metropolia University of Applied Sciences (UAS) in Finland.

During their second or third year of study, every student in all undergraduate programmes completes a MINNO® Innovation Project comprising ten credits, which is equal to approximately 270 hours of study time. The project's explicit aim is for the students to develop novel solutions, products, services or processes in response to authentic challenges presented by companies and other professional organisations (Metropolia UAS 2020; for further information on the implementation of the pedagogy, see Hero, 2020; Hero and Lindfors, 2019). In the beginning, students get to choose their preferred project challenge. Thereafter, to solve the challenge, students from different disciplines team up and form their own network of teachers, company representatives and other relevant stakeholders.

The instructive process includes orientation and theory along the way in the form of an innovation toolbox, team project work, concept presentations (i.e. pitches for the customer companies), customer caching, prototyping, research and testing, implementation and entrepreneurship planning, followed by a final public event and delivery to the customer. Teams are normally tutored for 1–2 days a week, and the customers give feedback on the solutions approximately 2–5 times. Typically, a team's project outcome includes concept papers, a prototype and its test results with productisation and a go-to-market sales and marketing implementation plan. The teachers act as facilitators and offer tools for innovating.

The teachers also help in networking and finding new partners from working life, if necessary. Grades are based on all project outcomes, customer and teacher observations, diaries and assessment discussions. Self-assessment questionnaire did not have on effect on grade.

In a single-group pre-test–post-test investigation, the pre-test data were collected during the first days of the 7-week MINNO® Innovation Project of the spring semester. The enrolled students received an invitation and a link to an electronic survey document. The responses were automatically directed to the archive of the e-document system, where they were also stored. Only the researchers had access to the archive. The post-test data were collected at the end of the 7-week project. The survey instrument as well as the arrangements for the data collection remained the same.

Whilst being aware of the weaknesses relating to the lack of control group, this quasi-experimental single-group pre-test post-design was considered appropriate for our study. There are two primary reasons for such a decision: Firstly, the pedagogical solutions used to facilitate the development of the learners' innovation competences at Metropolia, are practically oriented rather than lecture-based, hence, an equivalent control group was not available (Bowling, 2003; Campbell and Stanley, 1963). Secondly, finding an equivalent control group from another university with similar program offering was not seen as an option due to the lack of control with intervening variables, which would jeopardize the requirement for identical conditions (Bowling, 2003; Campbell and Stanley, 1963). Instead, in our study, the participants were used as their own control, which is a characteristic of repeated-measures designs (Loiselle and Profetto-McGrath, 2004).

A total of 430 students had enrolled in the project course, and they were all invited to participate in the pilot study. While not all the students were eligible, willing, or able to participate, the sample consisted of 138 students. The response rate was 32.1%. Of the 138 participants in the pre-test, 56 students (41%) also participated in the post-test survey.

Ethical clearance to conduct the study was granted by the Director of Research, Development and Innovation at Metropolia UAS in January 2020. The process also includes procedures to ensure adherence to the European Union General Data Protection Regulations, GDPR (2016/679) (European Union, 2016), as well as to the national Data Protection Act (1050/2018) in Finland. As outlined by the Finnish National Board on Research Integrity (2019), measures were taken to protect the dignity, rights and safety of the participants. The potential participants received information about the study, as well as an invitation to participate in it during the week before the kick-off of the MINNO® Innovation Project. The voluntary nature of participation and measures taken to ensure anonymity were explained, as well as the fact that the self-assessment scores were not in any way linked with the grading of the course. Only the researchers had access to the electronic archive that was used to store the original data. The students used individual ID codes to access the data-collection instrument; an individual cannot be identified via the codes, however. They were only used to allow the researchers to match the pre- and post-test replies of the same participant.

We analysed the quantitative data using SPSS version 25. Descriptive statistics (percentage, frequency mean, range, standard deviation [*SD*]) served to characterise the sample. The domains of the individual innovation competence were confirmed through explorative factor analysis and described with means and *SDs*. Following the factor analysis, the Cronbach's alpha coefficient was computed to measure the internal consistency reliability of the IIC Scale (Plichta and Kelvin, 2013). To compare the individual innovation competence before

and after the intervention, we used paired *t*-tests (Plichta and Kelvin, 2013; Nummenmaa, 2011). In this stage, we used the seven domains of the IIC Scale as sum variables.

To analyse the effects of the independent variables (age, study year, gender, field of study), we conducted a repeated measures analysis of variance (Plichta and Kelvin, 2013). The language of instruction was not included in this analysis due to the low number of participants in the English-language-taught group during post-testing ($n = 3$). This method was chosen as it allows for the measurement of the dependent variable (the sum variables illustrating the seven domains of the IIC Scale) over two or more time points and the exploration of the interaction between the independent and dependent variables. The following necessary assumptions for the analysis were met: the dependent variable was measured at the continuous level, the sum variables were matched pairs, there were no outliers in any combination of the related groups, the dependent variable was normally distributed in each combination, and the sphericity between all combinations of related groups was equal. Whenever the independent variable had more than two categories, the Bonferroni correction was used to counteract multiple comparisons.

Results of the pilot study

The IIC Scale comprised 87 statements. Each competence domain comprised several statements expressing the sub-domain (i.e. the factor) found in the systematic review and the complementary studies (see an example of one competence domain in Table 1).

Table 1. An example of one competence domain in the IIC Scale, its sub-domains and questionnaire statements.

Domain	Sub-domain	Questionnaire statement
Concretisation and implementation planning skills	Making skills	I know how to design practical items from abstract ideas I know how to make a working prototype I know how to make a functional product by hand I have crafting skills required for making a new concrete product I know how to use my sense of beauty in the realisation of a quality product
	Productisation planning skills	I know how to turn an idea into a product
	Marketing, sales and entrepreneurship planning skills	I know how to make a marketing plan I know how to make a sales plan for a product

To test our theoretical understanding of the IIC Scale, we assessed the internal consistency of the scale with the Cronbach's alpha reliability coefficient. The alphas ranged from 0.689 to 0.931 for the different domains of the scale (Table 2). All items in each domain appeared to be worthy of retention.

Table 2. Testing the internal consistency of the IIC Scale (n = 138).

Domain	Mean	Variance	Number of items	Chronbach's alpha
Personal characteristics	3.84	0.582	17	0.888
Future orientation	3.72	0.707	10	0.878
Creative thinking skills	3.70	0.717	13	0.912
Social skills	3.69	0.886	14	0.917
Project management skills	3.40	1.107	21	0.931
Content knowledge	3.36	0.962	2	0.689
Concretisation and implementation planning skills	2.59	1.732	10	0.926

The stability and precision of the IIC Scale across time was also examined by measuring the correlation of all seven domains before and after the intervention. In this test–retest examination, the Pearson correlation for *Personal characteristics* was 0.623, for *Future orientation* it was 0.520, for *Creative thinking skills,* 0.704, for *Social skills,* 0.708, for *Project management skills,* 0.708, for *Content knowledge,* 0.524 and for *Concretisation and implementation planning skills* it was 0.787. All results were statistically significant ($p < 0.001$). We also tested the content validity of the IIC Scale by conducting an exploratory factor analysis to confirm the structure of the IIC Scale. In this pilot phase, the data for analysis were too limited to make a reliable interpretation of the IIC Scale factors compared to the tested competence domains.

All seven innovation competence domains proved to be sensitive to change. All innovation competences post-assessed by students were higher compared to their pre-assessment levels. What was most sensitive to change were the capabilities that enable students to learn practical operational skills, such as managing their project work better, developing practical solutions, turning an idea into a product, or evaluating the threats and opportunities associated with entrepreneurship.

To compare whether students' individual innovation competence had significantly increased between measurements before and after the intervention, we used paired *t*-tests. The results of the domain-based paired *t*-tests are presented in Table 3. The sum variables are used here to illustrate the seven domains of the IIC Scale. In each of the domains, a significant difference in the scores was found between the before and after measurement outcomes. These outcomes suggest that the intervention had a positive effect on the development of individual innovation competence. Specifically, our results suggest that the positive effect is the highest

with *Project management skills*, $t(55) = -9.361$, $p < 0.001$, and with *Concretisation and implementation skills*, $t(55) = -10.279$, $p < 0.001$.

Table 3. The students' self-assessed individual innovation competence before and after the intervention in the domains of the IIC Scale ($n = 56$).

Domain	Mean	t	df	p value
Personal characteristics	-.37	-7.65	55	<0.001
Future orientation	-.34	-4.67	55	<0.001
Creative thinking skills	-.48	-7.67	55	<0.001
Social skills	-.41	-7.18	55	<0.001
Project management skills	-.58	-9.36	55	<0.001
Content knowledge	-.64	-6.88	55	<0.001
Concretisation and implementation planning skills	-.90	-10.28	55	<0.001

The weak effect of the multidisciplinary innovation project course in the domain of *Personal characteristics* was expected, as personal characteristics are supposed to be relatively stable patterns of thoughts, feelings and actions (cf. Costa and McCrae, 1988). What is also noteworthy is the relatively small change in *Future orientation*.

The most significant background determinant affecting self-assessment was the field of study. The respondents were distributed across different fields of study: nursing ($n = 17$), specialist healthcare ($n = 9$), rehabilitation ($n = 11$), social services ($n = 6$), culture ($n = 10$) and technology ($n = 3$). The students in specialist healthcare assessed themselves most critically and had the lowest pre-scores in all competence domains. The post-test indicated, however, that they had the highest increase in their competences. It seems that the starting level of one's own competence influences the assessment of the growth of one's competence after the intervention. The students of technology and social services most often assessed their skills as

the highest both in the pre- and post-tests. Such patterns were statistically significant with the domains of *Social skills* ($p = 0.009$) and *Project management skills* ($p > 0.001$). As the number of students in each group was small, the results may be considered indicative.

Male ($n = 18$) and female ($n = 37$) students seemed to have similar assessments of their competence development in all domains. Students under 25 years of age ($n = 22$) rated their innovation competence as slightly higher than those over 25 years old ($n = 34$) both before and after the intervention. In line with this was the observation regarding the year of study: Students in their first or second year ($n = 16$) rated their innovation competence as slightly higher than those in their third or fourth year ($n = 40$). None of these results were statistically significant, however.

Discussion and conclusions

As innovation competence is one of the key targets of higher education and an important part of entrepreneurship education, this study defined, developed and validated an individual innovation competence scale for university–industry learning interventions. To serve this purpose, the paper aimed to determine which individual innovation competences are significant in university–industry collaboration and which of these competences are sensitive to educational interventions in a multidisciplinary context. The paper reported the findings of the IIC Scale development and its pre–post-survey pilot tests. All seven domains of individual innovation competences defined in the first phases of the study were significant and sensitive to the piloted multidisciplinary innovation project educational intervention. An increase was found in each competence domain based on the students' pre- and post-self-assessments of their innovation competences. Previous IIC assessment scales in educational context have not included implementation related competencies although innovations by definition most often include the concrete form and implementation requirements (e.g. Peschl

et al., 2014; Quintane et al., 2011). The most responsive to change were the competence domains of *Concretisation and implementation planning skills* and *Project management skills*. The weakest effect of the educational intervention was in the domain of *Personal characteristics,* which was expected as personal characteristics are relatively stable patterns of thoughts, feelings and actions (Costa and McCrae, 1988). There were relatively low changes in the *Future orientation* domain (cf. Montani et al., 2014; Vila et al., 2014; Waychal et al., 2011). It is possible that the intervention did not include and develop future orientation, and it should be added more literally to pedagogy by the teachers. Of the background variables, only the field of study seemed to be associated with the change that occurred between the pre- and post-measurements. This finding must be considered with caution, however, due to the small number of participants in the study.

The scale seems to mirror the characteristics of university–industry innovation collaboration and the individual innovation competence related to it. If innovations are novelties that are made concrete, useful and implemented to convey value (e.g. Peschl et al., 2014; Quintane et al., 2011), competencies such as creativity may support the novelty requirement, and concretisation and implementation planning skills may support the requirement of concrete usefulness and go-to-market readiness. If innovation development is associated with teams of diverse individuals and networked multi-professional collaborations (Nandan and London, 2013; Sloep et al., 2014; Van Der Vegt and Bunderson, 2005), it is justified that the scale would highlight social collaboration, communication and networking skills. If the ambitious goal of producing an innovation requires multidisciplinary collaboration to produce a large number of high-quality original ideas and to collect the competence in a team that is needed in such versatile and multistage work (e.g. Jonassen et al., 2006; Kurtzberg, 2005), the scale

should also measure flexibility, responsibility, self-esteem, creativity and the development of project management skills.

The strength of this study is the transparency of the validation process and the ethical conduct of the empirical tests. Based on the rigorous and transparent validation process in authentic innovation development context, the bias-assessed systematic review background of the competency variables and domains and pilot test results, we are able to postulate that this scale is already usable in authentic innovation project contexts. However, there are limitations. The empirical validation tests were conducted with a limited number of participants. However, these participants already highlighted the development needs of the scale. One weakness of a pre–post survey may be that the *measuring stick* changes during the intervention as the respondent develops greater knowledge. At the beginning of the instruction phase, students may not know what they did not know, so they may give themselves higher ratings than they would at the end of the learning experience; that is, they may rate themselves as lower post-instruction (Howard, 1980). This limitation should be taken into consideration before drawing broader conclusions by using this quantitative survey method with some material collection and analysis providing with qualitative insight into the learning experience (e.g. diaries written during the project or assessment workshops in the beginning, middle and end of the project). Another weakness is the length of the scale. It still comprises 87 questions and thus takes 15 to 20 minutes to answer.

The findings indicate that despite the rigour of the validation and because of the limited materials, further research and tests are recommended. First, we recommend that the tool should be refined based on the pilot test analyses. Second, the tool should be tested with large participant groups in the same context. Third, the tool should also be validated for other contexts – namely, for entrepreneurs and corporate employees – to be able to compare the

student results with industry results. This could increase the understanding of the innovation potential as assessed by the people participating in innovation development networks. Fourth, the results raise the need to deepen our understanding of the relationship between pedagogy, industry targets and student learning experience in a multidisciplinary team to enable more efficient collaborations with working life to be designed. This also requires qualitative research.

In conclusion, the IIC Scale differs from other innovation competence scales in that it focuses on individual competence (cf. e.g. Kodama and Shibata, 2014; Lim et al., 2011; Wang, 2014), comprises a large number of items, is based on a systematic review and takes the implementation and exploitation phases of innovation development into consideration (cf. e.g. Edwards-Schachter et al., 2015; Keinänen et al., 2018). The major impact of this study is in the distribution opportunity following the pre- and post-survey validation of the IIC Scale. Future research with larger groups is possible after this initial validation study. As a practical implication, now that the development of the scale has been made transparent, it is possible to test and refine it with larger participant groups. It can then be distributed in different countries to compare the impact of best practices and pedagogical excellence in university–industry innovation and entrepreneurship education.

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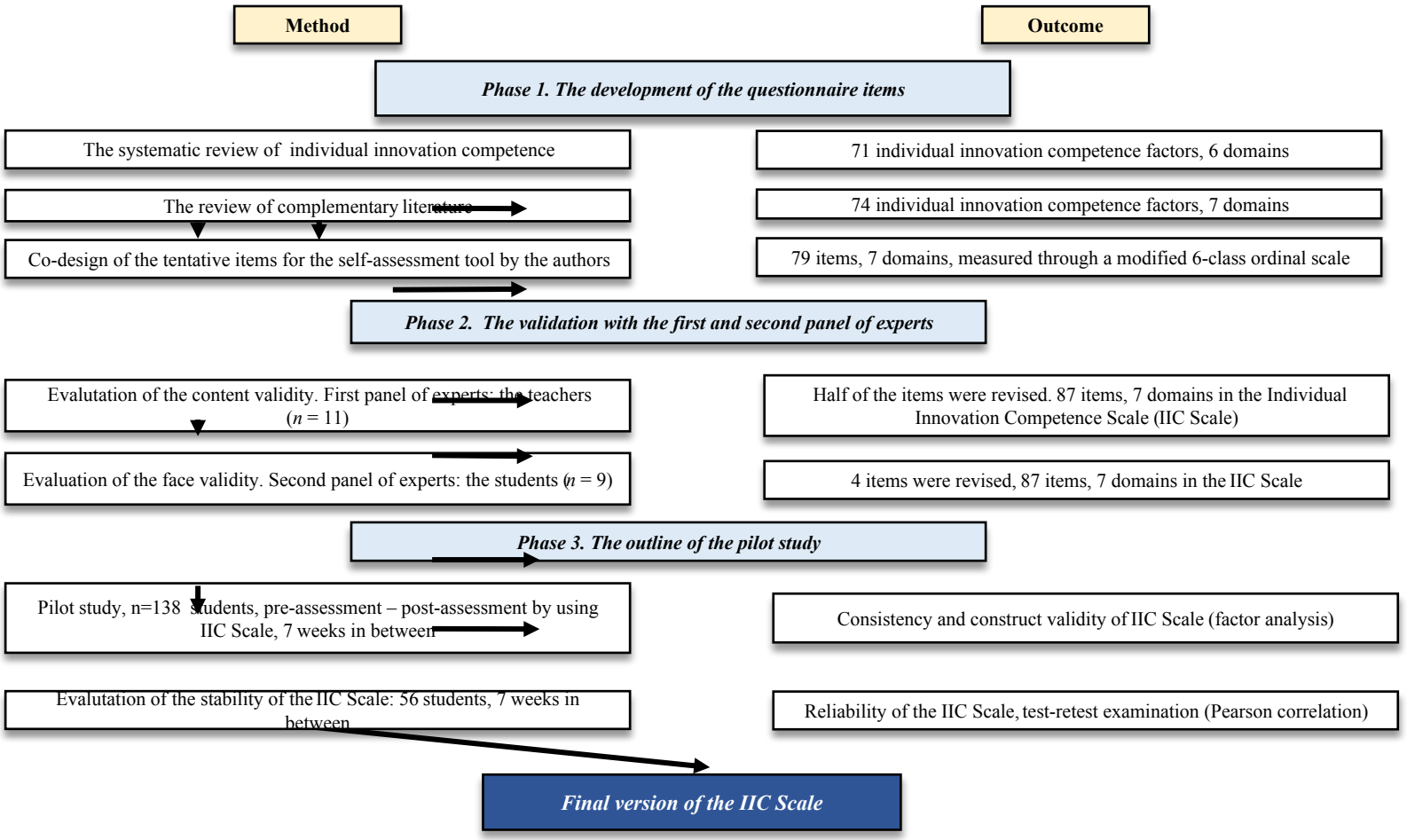
Method
Outcome
Phase 1. The development of the questionnaire items
The systematic review of individual innovation competence
71 individual innovation competence factors, 6 domains
The review of complementary literature
74 individual innovation competence factors, 7 domains
Co-design of the tentative items for the self-assessment tool by the authors
79 items, 7 domains, measured through a modified 6-class ordinal scale
Phase 2. The validation with the first and second panel of experts
Evalutation of the content validity. First panel of experts: the teachers (n = 11)
Half of the items were revised. 87 items, 7 domains in the Individual Innovation Competence Scale (IIC Scale)
Evaluation of the face validity. Second panel of experts: the students (n = 9)
4 items were revised, 87 items, 7 domains in the IIC Scale
Phase 3. The outline of the pilot study
Pilot study, n=138 students, pre-assessment – post-assessment by using IIC Scale, 7 weeks in between
Consistency and construct validity of IIC Scale (factor analysis)
Evalutation of the stability of the IIC Scale: 56 students, 7 weeks in between
Reliability of the IIC Scale, test-retest examination (Pearson correlation)
Final version of the IIC Scale

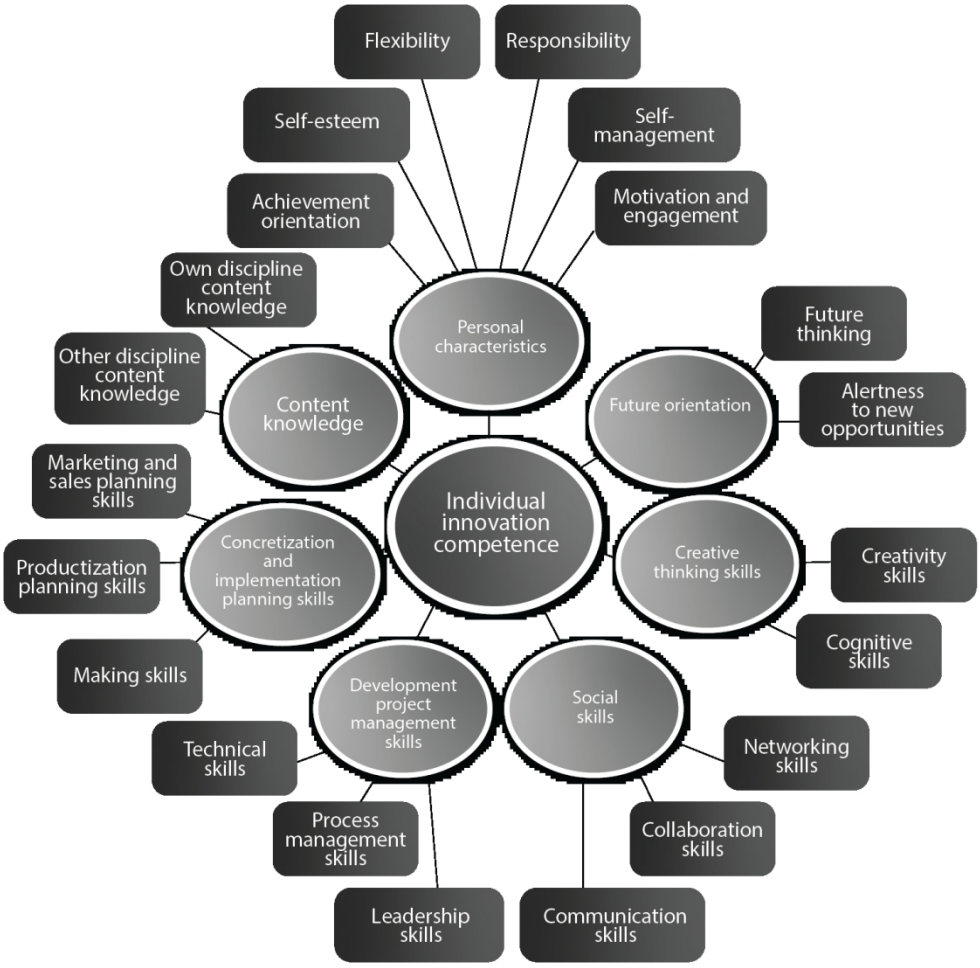

Figure 2. Sub-categories and domains of individual innovation competence identified for the development of statements (Hero et al., 2017; Hero, 2017; Hero and Lindfors, 2019).

Table 1. An example of one competence domain in IIC Scale, its sub-domains and questionnaire statements.

Domain	Sub-Domain	Questionnaire statement
Concretisation and implementation planning skills	Making skills	I know how to design practical items from abstract ideas
		I know how to make a working prototype
		I know how to make a functional product by hand
		I have crafting skills required for making a new concrete product
		I know how to use my sense of beauty in the realisation of a quality product
	Productisation planning skills	I know how to turn an idea into a product
	Marketing, sales and entrepreneurship planning skills	I know how to make a marketing plan
		I know how to make a sales plan for a product
		I can plan the utilisation a new product
		I am able to evaluate the threats and opportunities associated with entrepreneurship

Table 2. Testing internal consistency of the Individual Innovation Competence scale (n=138)

Domain	Mean	Variance	Number of items	Chronbach's alpha
Personal characteristics	3.84	0.582	17	0.888
Future orientation	3.72	0.707	10	0.878
Creative thinking skills	3.70	0.717	13	0.912
Social skills	3.69	0.886	14	0.917
Project management skills	3.40	1.107	21	0.931
Content knowledge	3.36	0.962	2	0.689
Concretisation and implementation planning skills	2.59	1.732	10	0.926

Table 3. The students' self-assessed individual innovation competence before and after the intervention in the domains of the IIC Scale (n = 56)

Domain	Mean	t	df	p value
Personal characteristics	-.37	-7.65	55	<0.001
Future orientation	-.34	-4.67	55	<0.001
Creative thinking skills	-.48	-7.67	55	<0.001
Social skills	-.41	-7.18	55	<0.001
Project management skills	-.58	-9.36	55	<0.001
Content knowledge	-.64	-6.88	55	<0.001
Concretisation and implementation planning skills	-.90	-10.28	55	<0.001