Learning to **innovate**

How to foster innovation competence in students of Built Environment at universities of applied sciences

Akugbe Robert Ovbiagbonhia

Propositions belonging to the PhD thesis, entitled

Learning to innovate

How to foster innovation competence in students of Built Environment at universities of applied sciences

Akugbe Robert Ovbiagbonhia

Wageningen, 8 November 2021

1. Teachers in built environment education highly overestimate the degree to which they are capable to create learning environments that support the development of innovation competence (this thesis)
2. Education stimulates innovation and creativity more than it kills it (this thesis)
3. Truly innovative research at universities is not possible, because traditional fields of science and vested faculties have the inclination to preserve themselves.
4. Although student-centered education is highly appreciated nowadays, we should not forget that our students need to be taught how to learn.
5. Policy makers too often drop innovations without being concerned about the implementation and evaluation.
6. Criticism is in the mind of the perceiver: being critical to someone may look like being reflective to others.

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General introduction

This introductory chapter highlights the relevance of innovation competence by addressing gaps within the previous literature, stating the objectives of the research, posing the research questions, and clarifying the significance of the research. The chapter ends with an overview of the thesis components.

1.1 Innovation competence relevance

Developing students' innovation competence is considered relevant by both scholars and educational policy makers. Nowadays, innovative workers are needed more than ever before. Every organization and business is currently being impacted by migration, climate change, technological and knowledge revolutions, and globalization issues (Beghetto & Kaufman, 2014; Messmann & Mulder, 2011; OECD, 2016; Sawyer, 2014). To deal with the modern-day complex societal challenges, organizations around the globe are in search of innovative employees. Innovation competence is necessary for solving many global problems, such as sustainable energy transitions, smart cities, smart industries and other social and environmental issues (Beghetto & Kaufman, 2014; Edwards-Schacter et al., 2015; C. Richardson & Mishra, 2018). Organizations and companies need innovation-competent individuals in order to survive in the changing world (Alsop, 2003; Beghetto, 2010; Edwards-Schacter et al., 2015; Keinänen & Kairisto-Mertanen, 2019; Kivunja, 2014; Sawyer, 2014; Tynjälä et al., 2003; Vila et al., 2012). Innovation competence as a form of human capital is a strong boost for the economy (Beghetto & Kaufman, 2014). Innovation often comes with added value and an increased employment base. As a result, innovation competence is emphasized in many educational policies, displaying the urgency of the need for innovation-competent professionals who are capable of participating in innovation processes and who can contribute to the creation of innovations. Innovation is imperative for the quality of life and may help to make the world a better place for younger generations.

Organizations expect higher education to equip graduate students with the competence to innovate in order for them to function well in ever-changing work environments (Alsop, 2003; Beghetto, 2010; Leavy, 2005; Nussbaum et al., 2005; Sawyer, 2014). According to Keinänen and Kairisto-Mertanen (2019), the role of higher education is not just to educate students for future work, but also to deliver innovation-competent students to society. Unfortunately, studies have shown that higher education in general is not yet doing enough to take up its responsibility to develop innovation competence in students and to prepare them for 21st century challenges (Fisher et al., 2011; Keinänen & Kairisto-Mertanen, 2019; Messmann & Mulder, 2011; C. Richardson & Mishra, 2018; Trilling & Fadel, 2009). The aforementioned scholars have argued that higher education needs to focus more on developing students' innovation competence via teaching and assessments of this competence to meet organizational and societal demands. As a result of the limited focus on innovation competence, which is not tied to a specific higher education domain, research is needed to identify relevant factors and ways that can foster innovation competence in students (Chan & Yuen, 2014; Fisher et al., 2011; C. Richardson & Mishra, 2018).

The EU has committed to endorsing programs fostering students' innovation competence (Bologna Process, 2015). Innovation competence has become essential for Built Environment design and construction organisations because of increasing pressures from clients to improve quality, develop sustainable construction solutions, develop new housing concepts to combat housing shortages and extreme temperatures, develop new building materials, reduce CO2, reduce construction costs and speed up construction processes (Dodgson et al., 2002; Gann, 2004; Xue et al., 2014). Considering this fact, it is important for Built Environment design and construction organisations to innovate in order to take advantage of changes in the market economy, build long-term relationships with clients, increase organisational motivation and make improvements to their systems and processes. Recognizing the need to ensure that graduates are equipped with the required innovation competence before their entry into the labour market, the Netherlands Association of Universities of Applied Sciences (Vereniging van Hogescholen) in 2015 emphasized the need to explicitly develop students' innovation competence in the Built Environment engineering domain. Since 2015, many Built Environment education programmes have been striving to explicitly educate innovation competence. Although the importance of the development of students' innovation competence was stressed by the Netherlands Association of Universities of Applied Sciences, specifications on how teachers should plan the curriculum for innovation competence were not provided. In addition, not much was said about what innovation competence is, what learning activities teachers should organize were not described, and how to assess the competence was not specified. Given this open assignment and the complexity involved in developing instructional strategies for innovation competence, it is expected that the existing learning environments may not yet be optimal for the enhancement of students' innovation competence (Choy & Cheah, 2009; Keinänen & Kairisto-Mertanen, 2019).

Innovation competence is a set of complex skills, types of knowledge and attitudes that are interrelated (Badcock et al., 2010; Chell & Athayde, 2009; Ursin & Hyytinen, 2010). Attempts to deconstruct innovation competence for the purpose of education have been few, and much of this literature focuses on creativity as a personality trait (e.g., Glynn, 1996; Mumford & Gustafson, 1988; Tierney & Farmer, 2002). The assumption there is that creativity can be equated with innovation competence, with no regard for other individual characteristics. Innovation competence has been viewed from many different angles by different scholars (see, for instance, Chell & Athayde, 2009; Costa & McCrae 1992; Keinänen et al., 2018; Kirton, 1976; Marin-Garcia et al., 2013; Patterson et al., 2009). Given the many perspectives on what innovation competence is and can be, there is little consensus on its definition and meaning (e.g., Bohlinger, 2012; Keinänen et al., 2018; Mäkinen & Annala, 2010; Pikkarainen, 2014). Typically, higher education policies, irrespective of domain, often do not explicitly describe what innovation competence is, leaving room for individual interpretation and uncertainty on the part of the educator (Barrie, 2007). According to Keinänen et al. (2018), comprehensive frameworks developed in educational contexts, explicating the teaching and learning activities involved in innovation competence education, are limited.

To foster innovation via education, scholars have recommended integrating the teaching and training of innovation competence and its various aspects into the curriculum (Chan & Yuen, 2014; Chell & Athayde, 2009; Fisher et al., 2011; Keinänen & Kairisto-Mertanen, 2019; Root-Bernstein & Root-Bernstein, 2017). However, not much is known about whether current higher education curricula indeed focus on the development of innovation competence and if so, to what extent (Beghetto & Kaufman, 2013). One way of knowing this is to map teachers' and students' views and perceptions concerning an innovation-supportive learning environment. As views on learning environments typically differ between involved participants (Fraser, 2012), the question is to what degree teachers' and students' views of innovation-supportive learning environments coincide, and whether the current learning environment is indeed sufficiently supportive of innovation competence development.

There is consensus in the innovation competence literature that education can play a central role in the development of students' innovation competence (Davies et al., 2013; Hu et al., 2016; Jones, 2009; Kasule et al., 2015; Keinänen & Kairisto-Mertanen, 2019). Studies have suggested, however, that higher education institutions are not sufficiently developing students' innovation competence (Badcock et al., 2010; Kasule et al., 2015; Keinänen & Kairisto-Mertanen, 2019; Tynjälä, 1999; Vila et al., 2012; Virtanen & Tynjälä, 2016). Previous studies, outside the domain of Built Environment, have shown that innovation competence is not yet explicitly part of actual teaching in higher education programmes (Beghetto & Kaufman, 2013; Edwards-Schacter et al., 2015) or assessment (Kivunja, 2014; Passig & Cohen, 2014; Root-Bernstein & Root-Bernstein, 2017).

A study by Jones (2009) revealed that although educational policy makers have emphasized the role and relevance of educating for innovation competence in higher education for decades, there has often been a lack of consistency between beliefs about innovation competence relevance and the degree to which innovation competence is focused on in classroom teaching practice. Studies have shown that innovation competence has not yet been addressed or has been addressed in very different ways in teaching (Beghetto & Kaufman, 2014; Choo, 2018; Edwards-Schacter et al., 2015) and assessment (Keinänen & Kairisto-Mertanen, 2019; Kivunja, 2014; Marin-Garcia et al., 2016; Passig & Cohen, 2014). This may be because educators in general do not have sufficient expertise or access to design principles or instructional strategies to enable them to foster innovation competence in their classrooms (Beghetto & Kaufman, 2014; Passig & Cohen, 2014; Root-Bernstein & Root-Bernstein, 2017).

Some scholarly work is available on the relevance of innovation competence (Beghetto & Kaufman, 2014; Edwards-Schacter et al., 2015) and on the characteristics of innovation competence supportive learning environments (Davies et al., 2013; Keinänen & Kairisto-Mertanen, 2019; Marin-Garcia et al., 2013; C. Richardson & Mishra, 2018; Sawyer, 2014; Vila et al., 2012). Yet, not much research exists on how to develop innovation competence in students via teaching. Research is needed to help higher education educators foster innovation competence in their students (Beghetto & Kaufman, 2014; Keinänen & Kairisto-Mertanen, 2019). In order to do so, higher education institutions need to know how to educate students in how to systematically discover problem gaps and articulate innovative problems (Beghetto & Kaufman, 2014; Root-Bernstein & Root-Bernstein, 2017), how to educate for and activate students' creativity, how to educate students in the process to follow to arrive at original and appropriate solutions to the articulated problem/question (Chan & Yuen, 2014; C. Richardson & Mishra, 2018; Sawyer, 2014; Vila et al., 2012), and how to educate for reflective practices and the relevance of demonstrating the effectiveness or shortcomings of the generated solution(s) to problems (Cross, 2002; Dym, 1994; Lumsdaine et al., 1999; Martindale, 1999; Marin-Garcia et al., 2013). Correspondingly, innovation competence is defined in this dissertation as the competence required to systematically discover problem gaps and articulate innovative questions, generate creative ideas for products, services, procedures, theories, demonstrate the usefulness or meaningfulness of the solution via reflective practices and show that the solution can be implemented successfully (Fisher et al., 2011; Messmann & Mulder, 2012; G. F. Smith, 2003; M. A. West & Farr, 1990).

1.2 Aims, positioning and structure

To address the aforementioned problems, the aims of this dissertation are to understand (1) the extent to which the existing curricula in Built Environment engineering education are innovation competence supportive and (2) how to foster innovation competence in higher education. By researching stakeholders' (students and teachers) views about the extent to which their existing curricula are directed towards the teaching of innovation competence, a better understanding of how to develop effective instructional principles for the design of innovation competence supportive teaching can be reached. The study in this dissertation is positioned within the field of innovation competence supportive learning environments in the higher education context. It consists of four studies that build on each other, using mixed research methods, and that follow overall an educational design research approach (McKenney & Reeves, 2019). This dissertation consists of two parts. The first part is a needs and context analysis (in which chapter 2 focuses on students and chapter 3 focuses on teachers), conducted via a survey research approach at eight Netherlands universities of applied sciences where innovation competence was set as a student attainment end goal. The second part contains the design and implementation of an intervention (chapters 4 and 5) within the existing curriculum of three Netherlands universities of applied sciences in which developing students' innovation competence was a learning goal. The following section provides an overview of the theoretical concepts and research questions.

1.3 Conceptual framework

Given the aims of this dissertation, an in-depth understanding of what innovation and innovation competence are is relevant to start with. Subsequently, we will discuss innovation competence supportive learning environments and the role of the perceptions and beliefs of teachers, followed by an outline of the research questions.

1.3.1 Innovation and innovation competence

The term 'innovate' is derived from the Latin word 'innovare', which means 'to renew, to make new'. According to G. F. Smith (2003), innovation is a way of problem-solving that begins with the feeling that change is needed and ends with the successful implementation of an idea. Idea generation, or creativity, is an integral aspect in the innovative problem-solving process (Messmann & Mulder, 2014). For innovation to take place, one must first develop a new idea before it can be implemented. Idea generation is often equated with the cognitive process of divergent and convergent thinking, which focuses primarily on the generation of multiple possibilities or scenarios rather than finding a single solution. The goal of ideation is to generate original and appropriate solution ideas or scenarios. The outcome could be in the form of innovative problems, services or products (Doolittle, 1995). Therefore, no innovation can occur without creativity. In many instances, the term creativity has been used to refer exclusively to the process of ideation, while at other times it has been used as a synonym of innovation (Unsworth et al., 2000). Whatever the orientation, creativity is closely linked with the process of innovation. Therefore, to be innovation competent, one must possess the necessary know-how, skills and attitudes related to problem identification, creativity in solution/idea generation and implementation of the solution or idea (Dai & Sternberg, 2004; Fisher et al., 2011; Messmann & Mulder, 2011).

Innovative problem-solving abilities require both cognitive as well as metacognitive or regulative aspects (Dezutter, 2011; Ericsson et al., 2006; Van Merriënboer & Kirschner, 2007). The cognitive aspects involved in innovative problem-solving include depth of domain-specific knowledge and skills, awareness of the problem situation, ability to collaborate, and knowledge about what characteristics of the task are adaptable (Ericsson, 2006). Metacognitive or regulative aspects involved in innovative problem-solving include creative self-efficacy (Bandura, 1997; Tierney & Farmer, 2011) and self-regulation (Zimmerman, 2006). Innovation can take different forms, from modest or incremental improvements on an existing product or process to dramatic changes. In all cases, to solve a problem innovatively requires huge commitment, having a vision of what one wants to accomplish and having a relationship with the circumstances one perceives that one is in (Slimane, 2015).

For the purpose of this research, we define innovation (following Smith, 2003 and Fisher et al., 2011) as the conscious ideation process of problem solving that begins with the urge to change, to generate new ideas, products and services, and ends with successful implementation. To arrive at an innovative solution in the form of a product or service, the idea must go through a process of development, from its discorvey to its implementation.

1.3.2 The innovation process

Innovation can be linked to stages, processes, or sequences (Egbu, 2004; M. A. West & Farr, 1989; R. E. West et al., 2012). The innovation process extends from the discovery of a new, applicable, and potentially useful idea to its transformation into a practically relevant outcome (King, 1992; M. A. West & Farr, 1989). According to models of creativity (Amabile, 1988) and innovation (M. A. West, 2002), the development of any innovation encompasses a multistage process of problem identification (problem discovery phase), the generation of ideas (creative phase) and the practical application and dissemination of ideas (implementation stage). These phases are non-linear and may overlap and occur simultaneously and repeatedly (Lubart, 2001). According to Messmann and Mulder (2012, 2014), the innovation process is a dynamic, context-bound construct, comprising interdependent innovation tasks (Kanter, 1988) that must be accomplished to successfully develop an innovation. According to Messmann and Mulder (2014), interdependent innovation tasks are iterative and partly build on each other, which makes the development of an innovation a complex process (Messmann & Mulder, 2012). Although different researchers have different ideas about the number of stages involved in innovation (see R. E. West et al., 2012; Wright et al., 2013), the bottom line is that innovation can be viewed as a process of interrelated sequences from idea generation to idea exploitation and that the process is subject to change (Egbu, 2004). Innovation competence is a multidimensional concept that can be viewed as a tool, set of skills, process or outcome (Chell & Athayde, 2009; Fisher et al., 2011; Wang et al., 2013). Therefore, the definition of innovation competence can be found in the process of innovation.

Innovation is conceived by many scholars as a process by which innovative questions are raised, creative solutions are generated for the questions raised and the implementation of the solutions is demonstrated (M. A. West & Farr, 1990). Following M. A. West and Farr (1990), we conceptualize the innovation process in this dissertation study to consists of three phases, namely: discovering innovative questions, generating creative solutions or ideas for the identified problem, and showing that the solution is implementable. First, *innovative problem discovery* involves individuals' receptiveness to recognizing the opportunity present within the context of a problem through creativity and research (Cross, 2002; Dym, 1994; Lumsdaine et al., 1999; Martindale, 1999). According to Martindale (1999), sensitivity to problem discovery is one of the most essential characteristics of many creative and innovative people in any field of human endeavour. In the view of Root-Bernstein and Root-Bernstein (2017), innovative individuals must first creatively formulate innovative questions before developing ways to solve the problem. Thus, the know-how to discover and formulate innovative problems is considered relevant for innovation. Second, *creative solution idea generation* is critical for innovation, as creativity is the backbone of innovation. It involves using different techniques to generate, evaluate and judge solutions for the defined problem (Amabile, 1996; Chan & Yuen, 2014; Fisher et al., 2011). Third, *solution implementation* is entirely a test phase and is iterative by nature, in which the emerging solution is validated, refined, restructured, presented, and promoted (Cross, 2002; Fisher et al., 2011; Lumsdaine & Binks, 2006).

1.3.3 Characteristics of the innovator

Innovation supportive education specifically aims to increase students' competence for discovering new opportunities or problems, generating creative solutions and demonstrating usefulness. To foster innovation competence, scholars recommend explaining the characteristics of innovative individuals and the process they follow to develop innovation (Amabile, 1996; Butter & Van Beest, 2017; Chell & Athayde, 2009; Fisher et al., 2011; R. E. West et al., 2012; Wright et al., 2013). As such, when studying innovation competence in this dissertation, on the one hand, we conceptualize it in terms of innovation subtasks and phases of the innovation process (see chapters 4 and 5), while on the other hand, we conceptualize it in terms of (trainable) characteristics that define an innovator (see chapter 2).

Below, we discuss the six most often discussed characteristics of innovators–*creativity, leadership, creative self-efficacy, energy, risk propensity and solving ambiguous problems* (Chell & Athayde, 2009; Hunter et al., 2012; Tierney & Farmer, 2002). According to Antonietti, Colombo and Pizzingrilli (2011), creativity is an integrated process of generating and developing original and appropriate solutions to problem. Leadership involves having a clear vision of the end goal, creating networks, collaborating with other experts, mobilizing and encouraging interest, organizing, and convincing and negotiating with other experts in order to achieve the goal (Dyer et al., 2009). Innovation requires persistence, proactive behaviour and drive (Chell & Athayde, 2009). Besides vigoro, commitment, and motivation are also required (Hunter et al., 2012), all of which are integral components of energy. Innovative individuals display relatively high self-confidence and beliefs about their own creative abilities (Tierney & Farmer, 2011). Studies have shown the link between creative self-efficacy and innovative behaviour in individuals (Tierney & Farmer, 2011; Wang et al., 2013). Ambiguity, complexity and lack of clear answers are characteristics of problems for which an innovative solution is required. Consequently, innovators are known by their ability to take calculated risks (Tabak & Barr, 1999). Innovative individuals are also willing to bring about change within a complex and ambiguous network of problems (Hurt et al., 1977; Keller, 2012). Hence, the competence to innovate can be expressed by one's inclination to be challenged by unanswered questions, ambiguities, and unresolved problems (Keller, 2012).

1.3.4 Innovation supportive learning environment dimensions, characteristics and strategies

Studies that have developed innovation supportive learning environments for students are scarce, regardless of the domain of study. Existing studies in higher education domains have either focused on measuring stakeholders' views of their learning environments or focused on an aspect of innovation competence, such as assessments and creativity (Cuenca et al., 2015; Watts et al., 2012). The learning environment dimensions, characteristics and strategies used are often not explicit. (Edwards et al., 2009; Edwards-Schachter et al., 2015). If we want students to develop innovation competence, which in this context means students' competence to identify an innovative problem or question, develop solutions for the problem and demonstrate the solutions' effectiveness, it is relevant to specify the dimensions, characteristics and strategies used in creating such learning environments. Accordingly, this dissertation hopes to provide insight for sorting out how the existing learning environments are innovation competence supportive by describing their relevant dimensions and characteristics and strategies for developing innovation supportive learning environments.

Innovation competence supportive learning environment dimensions - Here, we refer to an innovation competence supportive learning environment as meaning an environment intentionally designed to promote the learning of innovation competence, which is characterized by *emphasizing innovation*, focusing the content on *personal relevance*, and by s*tudent ownership of knowledge and control of learning processes* (Jeffrey, 2006). Many studies that have measured innovation competence have claimed to have created an innovative supportive learning environment simply because they measured innovation competence (e.g., Butter & Van Beest, 2017; Keinänen & Kairisto-Mertanen, 2019; Kivunja, 2014; Marin-Garcia et al., 2016; Passig & Cohen, 2014). Although these studies developed valid instruments to measure innovation competence, they did not measure or map an innovative supportive learning environment, in that no formal teaching was studied. According to Biggs and Tang (2011), an effective learning environment is one that aligns the teaching and learning activities with assessment. The development of innovation competence requires the accomplishment of a set of innovation tasks (Kanter, 1988) that trigger or support the three phases of the innovation process (Messman & Mulder, 2014). Other studies have reviewed stakeholders' perceptions of the presence of innovation supportive teaching in their learning environment (Hero, 2017; Kasule et al., 2015). These studies have shown that innovation supportive learning environments in higher education domains are not yet well developed, and that findings are often based on personal accounts rather than on research evidence (Beghetto & Kaufman, 2014; Choo, 2018; Edwards-Schacter et al., 2015). Their assessment is also not yet well developed (Keinänen & Kairisto-Mertanen, 2019; Kivunja, 2014; Marin-Garcia et al., 2016; Passig & Cohen, 2014; Root-Bernstein & Root-Bernstein, 2017).

Innovation competence supportive learning environment characteristics - Innovation competence is best developed in an environment where students are encouraged to solve authentic, real-world tasks, and to question the status quo (Kivunja, 2014; Michael, 2006). Past studies have revealed that educators need support, instructional guidance, and encouragement towards the fostering of students' innovation competence (Assink, 2006; Beghetto & Kaufman, 2014; Edwards-Schacter et al., 2015; Vila et al., 2012). According to Keinänen and Kairisto-Mertanen (2019), to train innovation competence, innovation supportive learning instruction is needed that can be integrated and aligned with the existing education curricula. An innovation supportive learning environment are often described as an environment where learning is achieved by the *active construction of knowledge, augmented with social interaction in solving real-world personally relevant tasks and negotiations between students and students and between students and teacher* (Driscoll, 2005; Fraser, 2012; Trilling & Fadel, 2009).

Innovation competence supportive learning environment strategies - To create an innovation competence supportive learning environment, three essential strategies are often employed (R. E. West et al., 2012; Wright et al., 2013). First, learners are engaged in solving authentic tasks. Authentic tasks are "real world" or contextualized tasks that are personally relevant or interesting to the learner (Duderstadt, 2008; Sheppard et al., 2009; R, E. West et al., 2012). Second, learners are encouraged to actively construct their understanding and create their own representations, instead of receiving information from a teacher (Crawley et al., 2007; Dyer et al., 2009; Wright et al., 2013). Third, learners are given the opportunity to engage in discussion, collaboration, and reflection (Dyer et al., 2009; Grasso & Burkins, 2009; Sawyer, 2006; Wright et al., 2013). For the students to engage in learning innovation competence in these authentic circumstances, it is necessary that the learning environment contains constructivist parameters, as described above. Constructivist learning principles have been used by various researchers in different learning domains to foster innovation related competence (e.g., Kwan & Wong, 2014; S. Lee & Taylor, 2001; Ozkal et al., 2009).

Regarding the learning environment, many researchers and educational practitioners have advocated that teachers' perceptions of the classroom environment play a fundamental role in fostering innovation competence (e.g., Bassett, 2004; Davis & Rimm, 1998; Sternberg & Williams, 1996). Understanding students' and teachers' perceptions of features of the learning environment is critical in fostering students' innovation competence, since previous research has revealed that perceptions of the learning environment affect students' learning in general (Aldridge & Fraser, 2011; Fraser, 2007, 2012) and their innovation competence development more particularly (Chan & Yuen, 2014). To improve our understanding of how to support students' development of innovation competence and in turn support teachers in creating a supportive learning environment for such development, an important step is to understand how students and teachers perceive and experience the learning environment regarding development of innovation competence at the school and classroom levels. The beliefs that teachers hold about their own ability to foster innovation competence in students (Tierney & Farmer, 2002) and whether it is relevant to teach innovation competence are also relevant areas of study (Ajzen, 2002).

1.3.5 Teacher beliefs and perceptions of the innovation competence learning environment

The teacher's role is indispensable with respect to preparing students to become innovative individuals who can find implementable solutions to future challenges. According to Wilcox-Herzog (2002), the role of teachers in realizing educational aims and purposes is vital, because teachers direct the teaching and learning processes, and they are the nearest practitioners to learners. Teachers are responsible for structuring the learning environment to integrate attention to their students' innovation competence. However, teachers' behaviours and decisions in shaping a learning environment are greatly influenced by teachers' beliefs (e.g., Mansour, 2013; Olafson & Schraw, 2006). As a result, teachers' beliefs about fostering innovation competence in students need to be taken into account (Newton & Newton, 2009), especially in the Built Environment educational domain, where a traditional teaching style is favoured.

In the literature, various terms have been used to describe beliefs (Andiliou & Murphy, 2010). Bandura (1997), regards beliefs as the major driver for goals, emotions, decisions, actions, and reactions. In this dissertation, perceptions are distinguished from beliefs for purposes of clarity. In learning environments research, perceptions are often distinguished from beliefs (Fraser, 2012), with the assumption that the perceptions are partly determined by the beliefs. We use the term *perception* to mean the interpretations of students and teachers of what they observe and experience in the learning environment with respect to innovation competence instruction (Fraser, 2012). The term *beliefs* is used to mean the opinions of the teacher with respect to innovation competence relevance and the confidence the teacher has about fostering innovation competence in students (Tierney & Farmer, 2002).

The literature has reported that the perceptions and beliefs of teachers affect teaching (Ajzen, 1991). In a systematic literature review on teachers' roles and what is necessary for promoting creativity, Davies et al. (2013) concluded that teachers need to have a *positive attitude towards innovation and need to feel confident about their own creativity in teaching.* To effectively teach students to become innovative, the teacher needs to be confident about his/her knowledge and ability to teach innovation competence (Beghetto et al., 2011; Tierney & Farmer, 2002). Innovation competence supportive teaching requires a shift from teacher-centred teaching to a student-centred teaching approach (Konst & Scheinin, 2018; Trilling & Fadel, 2009). According to Keinänen and Kairisto-Mertanen's (2019) study, effectiveness in teaching innovation competence can be realized when a teacher's beliefs shift from teaching basic knowledge to teaching applied skills, from teaching facts to teaching principles about questioning, creativity, and problem analysis, from teaching mere theories to teaching how to use theories to resolve practical problems and from working with a fixed curriculum to engaging students in real-world authentic problems.

1.4 Research questions

This dissertation study will contribute to the limited body of research on Built Environment education that focuses on the issue of innovation competence instruction. Therefore, the aim of this dissertation is twofold: a) to explore students' and teachers' perceptions of the existing curricula aimed at fostering students' innovation competence, and b) to develop and evaluate design principles for innovation competence supportive learning environments.

To achieve these goals, the following research questions will be answered in this dissertation:

1. To what degree do students of Built Environment education at universities of applied sciences perceive the existing learning environment as supportive for developing innovation competence, how do students perceive their own innovation competence and to what degree are their perceptions of the learning environment and of their competence related?
2. To what degree do teachers of Built Environment education at universities of applied sciences perceive their learning environments as supportive for developing innovation competence, what beliefs do they hold about innovation competence instruction and what is the interplay between these beliefs and perceptions?
3. On what design principles can innovation competence instruction be based and how can an instructional intervention be successfully implemented in practice?
4. To what extent is the innovation competence instructional intervention, based on the design principles for innovation competence-supportive teaching, effective in increasing students' innovation competence?

As mentioned earlier, these questions were pursued through an educational design research approach (McKenney & Reeves, 2019), starting with exploration of the context with respect to the existing curricula focused on innovation competence instruction, followed by the design and construction of effective design principle to aid the design of innovation competence instruction; and moving on to the evaluation of and reflection on innovation competence instruction.

1.5 Research approach

The research in this dissertation can be considered in its entirety as educational design research. This is a research approach for producing new theories, artifacts, and practices that accounts for and potentially impacts teaching and learning in naturalistic settings (Barab & Squire, 2004). That research approach is employed here to pursue the research goal of developing an effective learning environment for innovation competence learning (McKenney & Reeves, 2019; Sandoval & Bell, 2004). The design process is guided by sets of principles (Eldelson, 2002). The principles were applied by following iterative cycles of design and implementation, using each implementation as an opportunity for data collection to inform subsequent (re)design of the innovation competence instruction prototype. In educational design research, through parallel and retrospective processes of reflection upon the design and its outcomes, the designers elaborate upon the initial principles, refining, adding, and discarding (McKenney & Reeves, 2019). Educational design research is an iterative and flexible process that consists of three interrelated phases (McKenney & Reeves, 2019); see Figure 1.1 below.

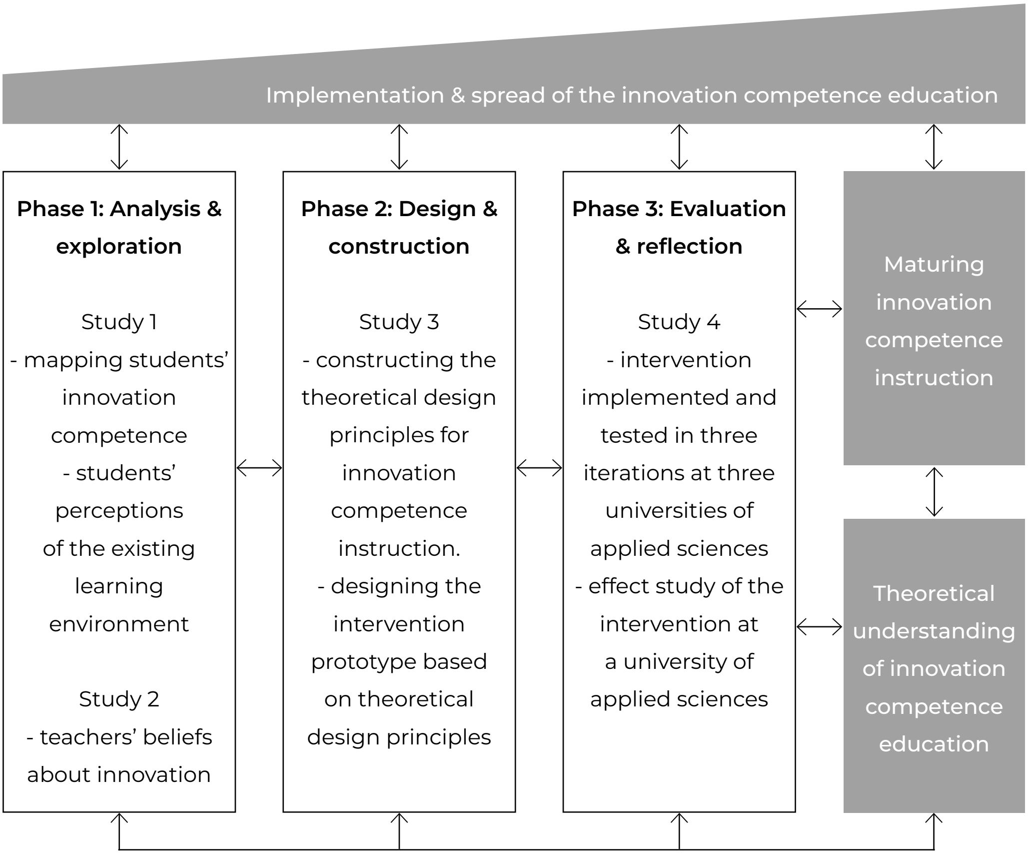

Figure 1.1 Illustrates the connection between the generic model for conducting educational design research (McKenney & Reeves, 2019) as the research approach and the studies. The arrows depict key relationships between the concepts, not causal relationships. The study numbers also refer to the research questions above.

Following the description given above, research activities guided the development of an innovation competence intervention. The basis for realizing the research objectives was created early in the study, which was how to implement feasible and effective innovation competence instruction. These guiding principles for innovation competence instruction (chapter 4) were based on insights gained from the innovation competence literature, augmented by insights gained from the needs and context analysis (chapters 2 and 3). Data collection during each iteration (chapter 5) yielded information on how to refine the design principles and whether the desired impact or goal of the innovation competence instruction was attained. Based on these reflections, the design principles for innovation competence instruction were refined during the course of the iterations.

The practical benefits of the educational design research approach as used in this dissertation is in the direction of lasting improvements in students' innovation competence via the teaching intervention that was developed. The studies in this dissertation aim to make a valuable contribution to the field of innovation competence instruction by providing insight into the state of affairs of innovation competence instruction in the Built Environment engineering domain of higher education, by recommending desirable and feasible characteristics and components of innovation competence development, and by providing strategies to support the implementation of innovation competence instruction in practice. This dissertation also aims to make a valuable theoretical contribution to innovation competence education, particularly in higher education domains and beyond. It aims to do so by yielding theoretical knowledge (design principles) about how to design and build innovation competence interventions in the context of higher education. The following sections briefly discuss the research context, data, and methods.

1.5.1 Research context, data, and methods

Throughout this dissertation, educational design research was used as the overarching approach. The four studies approached innovation competence from different perspectives, whereby the research participants, methods, and data collection approaches differed (see Figure 1.1). The research context consisted of Built Environment engineering education at eight universities of applied sciences, where innovation competence was students' targeted learning goal. In the Netherlands, universities of applied sciences have the autonomy to prepare their own pedagogical approach to teaching and learning, so that different approach to innovation competence can be assumed. Data for studies 1 and 2 were collected in the year 2016 at eight universities of Applied Sciences. While data for studies 3 were collected in the years 2017 to 2018 at three universities of Applied Sciences. Data for studies 4 were collected in the years 2018 to 2019 at one universities of Applied Sciences.

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The first study relied on quantitative data on students' ($n = 130$) self-assessment of their innovation competence and their perceptions of the degree to which the existing learning environments they were in were aimed at innovation competence, collected via a constructed survey. The second study also relied on quantitative data on teachers' ($n = 94$) self-assessment of their creative self-efficacy, their beliefs about innovation competence relevance and their perceptions of the degree to which the existing learning environments were aimed at innovation competence, again via a survey. In addition, teachers' and students' perceptions of the learning environments were compared. The third study described theoretical design principles that formed the basis for an instructional prototype. The fourth and final study was a mixed methods study using surveys, interviews, and students' course products, and investigated the effectiveness of the innovation competence prototype at one university of applied sciences; during its development, prior iterations were each tested at a different university of applied sciences. The following sections discuss the individual research phases as depicted in Figure 1 above in more detail.

Based on the recommendations offered by McKenney and Reeves (2019), the development of the innovation competence instruction intervention took place through several iterations. In total, the dissertation consisted of three phases. The needs and context analysis phase involved two studies that were conducted at eight universities of applied sciences in the Built Environment engineering domains. The design and construction phase was described in one study. The implementation and evaluation phase involved an initial three iterations, each at a different university of applied sciences. After these iterations, the resulting intervention was evaluated in a fourth iteration at a different university of applied sciences than those at which the first iterations occurred.

Analysis and exploration phase - This phase involved a literature review and a needs and context analysis through the exploration of relevant stakeholders' viewpoints of the problem and solution space (McKenney & Reeves, 2019; van den Akker et al., 2006). The goal of this phase was to generate a clear picture of the educational problem and to develop design principles for developing and measuring an effective solution to the problem. The needs and context analysis provided information about the learning requirements of the Built Environment engineering students and the contextual factors (for example, perceptions of the existing learning environments, teachers' beliefs, attitudes, and knowledge about innovation competence) that were likely to influence students' innovation competence development processes. The needs analysis study led to the formulation of targeted objectives for innovation competence instruction development activities. The study 1 & 2 were conducted via a survey that was administered at the beginning of the academic year in 2016. The first study (chapter 2) explored students' perceptions of the existing learning environment in relation to innovation competence instruction and self-perceived rating of their own innovation competence. The second study (chapter 3) mapped teachers' beliefs about innovation competence relevance, their self-efficacy beliefs about innovation competence instruction and focus on innovation competence instruction, and perceptions of the existing learning environment in relation to innovation competence instruction.

The findings from the needs and context analysis and a review of relevant literature helped gain an understanding of the existing learning environment with respect to innovation competence instruction. This, in turn, led to the development of the design principles that shaped the development of the innovation competence intervention (chapter 4).

Design and construction phase - This phase (chapter 4) comprised a systematic and structured process, oriented towards the development of the conceptual solution to the educational problem without much emphasis on testing (McKenney & Reeves, 2019). Here, the conditions or guidelines for a good solution were formulated in the form of design principles. The design principles informed the process of developing the instructional prototype for the innovation competence intervention through formative evaluation and systematic revision of the design principles. While a general review of relevant literature that helped inform the exploration of the problem was conducted in the first phase, a second inspection of the literature was conducted in this phase to find relevant theory for the design principles upon which the instructional prototype for innovation competence could be based. Relevant learning theory together with the design principles guided the intervention.

Evaluation and reflection phase - This phase (chapter 5) involved a systematic and structured process oriented around the implementation and testing of the instructional prototype (design principles). This study involved multiple (re)design cycles, in which the innovation competence instruction was designed, modified, and implemented. Formative evaluation was undertaken with the first and second prototypes. The first design and formative evaluation took place in the first period of the first semester of 2017 and pertained to the initial pilot involving first-year Built Environment engineering students. Based on insights from this first iteration, the second cycle took place in the third period of the second semester of 2017, involving second-year Built Environment engineering students at another university of applied sciences; this entailed modifying and implementing the innovation competence instruction prototype, which was followed by a second formative evaluation. The third cycle took place in the first period of the first semester of 2018, and also involved second-year Built Environment engineering students; this took place at another university, including another round of revision and implementations. The fourth and final design was implemented in the first period of the first semester of 2018, involving final-year Built Environment engineering students, and underwent summative evaluation. By following these phases repeatedly, the innovation competence instruction presented as the main goal of this dissertation study emerged.

The fourth and final design involving final-year Built Environment students at a university of applied sciences was evaluated differently from those involved during the design and construction phase. The final study to evaluate the effects of the prototype included a pre- and post-test of students' (n = 46) self-perceived innovation competence ; semi-structured interviews with a subset of these students (n = 18); semi-structured interviews with teachers (n = 2); and analysis of students' (n = 46) products, as assessed by 12 teachers. The summative study was conducted to assess the immediate impact of the innovation competence instruction. The chapters in this dissertation were written in the form of separate articles. As a consequence, some overlap of text may exist in the introduction, theoretical backgrounds, designs and limitations of the various chapters in this dissertation.

Table 1.1 Overview of the dissertation

	Study subject	Study aim	Study design, data collection & data analysis	Output
Chapter 1	Introduction			
Chapter 2	Students' innovation competence and perceptions of the innovation competence supportive learning environments	Mapping students' perceptions of the learning environment, the extent to which their schools' curricula were directed towards developing innovation competence, and their perceptions of their own innovation competence	Survey study: multiple regression analysis	Insight into students' perceptions of their own innovation competence and of the learning environments aimed at developing innovation competence
Chapter 3	Teachers' beliefs and perceptions of the innovation competence supportive learning environments	Investigating teachers' beliefs about innovation competence relevance, their creative self-efficacy and comparing teachers' and students' perceptions of the learning environment	Survey study: t-test; multiple regression analysis	Insight into teachers' beliefs about innovation competence and relevance, and their perceptions of the existing learning environment
Chapter 4	Six design principles for	Defining and discussing the design principles capable of assisting teachers in developing innovation competence supportive teaching	Literature review	Practical output for teachers: six design principles; three learning outcomes; tasks description; assessments rubric
Chapter 5	Innovation competence training	Describing the effects of innovation competence training (ICT) as implemented in the existing curriculum at a Netherlands' university of applied science (UAS) Built Environment department	Empirical study of pre- and post-test, focus group interviews with students, teacher interviews and product assessments	Insight into effects and suitability of the innovation competence intervention
Chapter 6	Discussion and conclusions			

2

Educating for innovation: students' perceptions of the learning environment and of their own innovation competence

This chapter investigates the existing learning environment as it relates to innovation competence in higher education context. It is focused mainly on mapping students' perceptions of the learning environment and of their own innovation competence. It is critical to investigate students' perceptions of their learning environments, especially in the higher education setting, giving the limited research in this sector.[1]

[1] This chapter is based on: Ovbiagbonhia, A. R., Kollöffel, B., & den Brok, P. (2019). Educating for innovation: students' perceptions of the learning environment and of their own innovation competence. *Learning Environments Research*, 22, 387–407. DOI 10.1007/s10984-019-09280-3.

2

Abstract

Developing students' innovation competence is becoming increasingly important in higher education, yet few studies have investigated whether current learning environments are aimed at promoting this competence and whether students perceive themselves to have mastered this competence. This study aimed at mapping students' perceptions of the learning environment as far as the extent to which their schools' curricula were directed towards developing innovation competence and their perceptions of their own innovation competence. A survey was created and administered to 130 students of Built Environment programs at eight universities of applied sciences (UAS) in the Netherlands. Students perceived there to be a supportive learning environment for innovation competence only to a limited degree. On the other hand, students rated their own innovation competence moderately high. Despite positive perceptions of students' own innovation competence, the results indicated that the learning environment was only to a limited degree aimed at developing innovation competence. The results suggest that universities may need to focus more explicitly and structurally on the teaching and assessment of innovation competence.

2.1 Introduction

In response to society's growing need for professionals with strong 21st century skills, many educational institutions are looking for ways to foster the innovation competence of their students (C. Richardson & Mishra, 2018; K. Robinson, 2011; Wagner, 2010). Environments that support the development of innovation competence are less structured and more hands-on, represent multiple ways of learning, and have a less rigid teachers' role than in traditional learning environments (Dalke et al., 2007). In a learning environment that supports development of innovation competence, learning goals are explicitly articulated, teaching is directed towards realizing these goals at both the school and classroom levels and students perceive their learning to become innovative as important for their future personal and career development (Beghetto & Kaufman, 2014). Such an environment emphasizes the importance of making learning personally relevant for the learner through connecting the teaching activities within school to out-of-school experiences by engaging students in authentic tasks (Jonassen, 1994; Lim & Sato, 2006). In a learning environment that supports innovation competence, students are also provided with opportunities to negotiate with their teachers, stakeholders and with each other about what to learn and how best to learn it (Burgess & Addison, 2007; Rutland & Barlex, 2008). Finally, in environments that support the development of innovation competence, students learn about the uncertainty of scientific knowledge, that scientific knowledge is evolving, that it is created through theory-dependent learning, involves human experiences and values, and is socially and culturally determined (Fraser, 2012).

According to Beghetto (2010), there is tremendous interest in developing innovation competence in educational settings, and as a result the number of studies focusing on this has grown. However, not much is known about how students perceive learning environments intended for innovation competence development (Beghetto & Kaufman, 2014). Much of the previous research in the field of innovation competence has focused mainly on individual, psychological, and/or personality variables in relation to innovation competence, which is very important, but offers minimal practical advice to teachers (Beghetto, 2010). Learning environments intentionally designed for innovation competence development and students' perceptions thereof are areas that have not received much attention in the educational research literature (Beghetto & Kaufman, 2014; C. Richardson & Mishra, 2018).

It is critical to investigate students' perceptions of their learning environments, especially in the higher education setting, given the limited research in this sector. While many teachers may believe that developing students' innovation competence is relevant, they may lack the know-how to do so (Chan & Yuen, 2014). Research on learning environments has also demonstrated a link between students' perceptions of the learning environment and their learning outcomes (Dorman & Fraser, 2009). Students' perceptions of the learning environment predict an appreciable amount of variance in learning outcomes (Dorman & Fraser, 2009). Therefore, investigating students' perceptions of the learning environment is a valid way to improve learning outcomes (Fraser, 2012).

Understanding students' views about features of the learning environment is critical in fostering students' innovation competence, since previous research has revealed that the learning environment is an important variable that affects student learning in general (Aldridge & Fraser, 2011; Fraser, 2007, 2012) and their innovation competence development more particularly (Chan & Yuen, 2014). To improve our understanding of how to support students' development of innovation competence and in turn support teachers to create a supportive learning environment for such development, an important step is to understand how students perceive the learning environment with regard to development of innovation competence at the school and classroom levels.

Past studies in the domain of learning environments have demonstrated the effectiveness of using learning environment variables in the evaluation of student learning (Bell & Aldridge, 2014; Martin-Dunlop & Fraser, 2008). However, our review of the literature suggests that there have been no studies that have examined students' perceptions of a learning environment directed at innovation competence in general, and in the domain of Built Environment in particular. Therefore, this study aims to fill this gap in the literature and to extend research in the field of learning environments by measuring students' self-perceived innovation competence and their perceptions of features of existing learning environments aimed at innovation competence, as well as investigating the association between these two elements.

In the next section, we will briefly describe the concept of innovation competence, the components of innovation competence and, finally, the characteristics of a supportive learning environment for developing innovation competence.

2.2 Conceptual framework

2.2.1 Creativity, innovation and innovation competence

While *creativity* is the generation of novel, unique, and useful creative ideas, *innovation*, on the other hand, involves the successful implementation of creative ideas, products, services, procedures, theories, and strategies (M. A. West & Farr, 1990). This implies that before people can become innovative, they need to be skilled in identifying performance gaps where innovative solutions are needed, in generating creative ideas and in transforming these creative ideas into realistic, practical, and marketable solutions (Bel, 2010). Innovation competence is, therefore, the competence to develop creative ideas for products, services, procedures, theories, and strategies that are useful or meaningful to the intended audience, and that can be implemented successfully (Tidd & Bessant, 2009; M. A. West & Farr, 1990). Innovation competence, like any competence, involves the integration of knowledge, skills, and attitudes. Innovative individuals have been reported to have a high level of creative abilities and leadership abilities, to be highly persistent and task motivated, to display a high level of creative self-efficacy, to have the propensity to take calculated risks and to like working on ambiguous and complex problems (Chell & Athayde, 2009; Hurt et al., 1977; Tierney & Farmer, 2002).

The literature is quite elaborate about the components of innovation competence that should be developed, and several conceptual descriptions of innovation competence exist, which vary tremendously (Chell & Athayde, 2009; Dyer et al., 2009; Hurt et al., 1977; Pérez-Penalver et al., 2018; Tierney & Farmer, 2002). Similarly, many studies have been devoted to different groups or contexts for innovation, such as firms and organizations, (S. G. Scott & Bruce, 1994) or consumers (Hurt et al., 1977; Price & Ridgeway, 1983). These studies were sometimes very generic (Hunter et al., 2012; Jackson & Messick, 1967) and sometimes very specific to designated domains, such as engineering (Dyer et al., 2009; Fisher et al., 2011; Keller, 2012; Ragusa 2011), or types of education, such as secondary education (Chell & Athayde, 2009). From the literature, six interrelated characterises/antecedents that make innovators competent to innovate come to the fore: *creativity*, *leadership*, *creative self-efficacy*, *energy*, *risk propensity* and *solving ambiguous problems*. For purposes of clarity, we discuss the elements individually, but in practice they are interconnected.

Creativity - Researchers have regarded creativity as a strong component of innovation competence (Hurt et al., 1977; Chell & Athayde, 2009). According to Antonietti, Colombo and Pizzingrilli (2011), after the recognition of a problem or an area where an innovative solution is needed, that idea needs to be further developed by the integrated processes of widening, connecting, and restructuring. Widening means: keeping an open mind; being aware of the great number of elements that can be identified in a given situation; recognizing possible, not obvious meanings; discovering hidden aspects and overcoming apparent constraints. Connecting entails the competence to establish reciprocal relationships among different elements, such as by thinking in scenarios, drawing analogies between remote things, combining ideas in odd ways, and synthesizing a multiplicity of disparate elements into an overall structure. Restructuring involves looking at problems or solutions from different perspectives, which can include seeing things differently by inverting relationships between their elements, asking original questions, and imagining what should happen if unusual conditions occur.

Leadership - Innovation competence is highly dependent on leadership skills, as no innovation takes place in isolation (Chell & Athayde, 2009; Hurt et al., 1977). Leadership involves having a clear vision of the end goal, networking, collaborating, mobilizing, organizational ability, and convincing other experts in order to actualize the goal (Dyer et al., 2009; Jung, 2011; Jung & Sosik, 2002).

Creative self-efficacy - The concept of creative self-efficacy is supported by Bandura's (1997) self-efficacy theory, which describes self-confidence and beliefs about the self in terms of having the required knowledge, skill and ability to perform a specific task. Creative self-efficacy, therefore, is the degree to which a person displays confidence in solving problems creatively (Tierney & Farmer, 2002). Previous studies have linked self-efficacy to creative behaviour in individuals (Tierney & Farmer, 2011; Wang et al., 2013).

Energy - Persistence, proactive behaviour, and drive have been associated with innovation competence by different authors (Chell & Athayde, 2009; Ryan & Deci, 2000; Sahlberg, 2009). To fully develop an innovative idea requires having a clear vision of the end destination, which in turn requires vigoro, commitment, and motivation (Hunter et al., 2012).

Risk propensity - Real-life problems are often ambiguous, complex and devoid of clear answers. Risk avoidance can result into a person being reluctant to innovate (M. A. West, 2002). Conversely, people willing to take risks are more likely to be innovative (Tabak & Barr, 1999). It takes confidence and risk-taking on the part of the innovator to get a creative idea to mature to the implementation or innovation stage (Campbell et al., 2004).

Solving ambiguous problems - This concept describes a person's willingness to change and to innovate within a complex and ambiguous network of problems (Hurt et al., 1977; Keller, 2012). Consequently, innovation competence could be expressed by one's inclination to be challenged by unanswered questions, ambiguities, and unresolved problems (Keller, 2012).

The competence to innovate can be cultivated. However, the role and relevance of a supportive learning environment in this respect must be spelled out. In the next section, we will describe what makes such an environment.

2.2.2 Components of learning environments that foster the development of innovation competence

The context or specific setting (social and cultural) that is intentionally created to support learning is often referred to as an environment, milieu, or climate (Fraser, 2012). This includes the psychological factors, the classroom teaching, and the physical factors of any place where learning occurs, including virtual and non-traditional spaces (Fraser, 2012).

Learning environments that focus on the development of innovation competence start with the recognition of this competence as a key educational goal and an essential 21st century skill that should be supported in schools (Chan & Yuen, 2014; K. Robinson, 2011; Wagner, 2010). In creating such an environment, a constructivist approach is generally suggested (Ertmer & Newby, 1993). In constructivist learning environments, learners are encouraged to actively construct their understanding and make their own representations, instead of receiving information from a teacher. According to Jonassen (1999), in a constructivist learning environment, learners are given tools that enable them to engage in discussion, collaboration, and reflection. Constructivist learning environments engage the learner in solving authentic tasks. Authentic tasks are "real world" or contextualized tasks that are personally relevant or interesting to the learner (Brookes et al., 2012; Jonassen, 1999; Thao-Do et al., 2016), and therefore they are considered particularly suitable for effective innovation competence development (Li et al., 2012).

Several dimensions of constructivist learning environments that are relevant for promoting innovation competence have been identified in the literature. Below, we briefly discuss some relevant dimensions of constructivist learning environments that are emphasized in this study. Subsequently, we will discuss some prior research on learning environments that has studied constructivist learning environments with the same instrument used in the present study, the Constructivist Learning Environments Survey (CLES; Taylor et al., 1995). The CLES has been used by several researchers, especially in the domain of primary and secondary education, to map students' perceptions of dimensions that constitute a constructivist learning environment, such as uncertainty, student negotiation and personal relevance. The CLES enables educators and researchers to measure students' perceptions of the extent to which constructivist approaches are present in classrooms (Taylor et al., 1997). We selected the CLES for this study because of its proven ability to capture specific dimensions of a constructivist learning environment and because of its demonstrated strong factorial validity and reliability in numerous countries (Fraser, 2012). Before discussing the empirical findings and insights that have been obtained using this instrument, we will first briefly introduce the specific dimensions it addresses, followed by a discussion of relevant past research.

Personal relevance is the extent to which the content used in the constructivist learning environment is relevant to students' everyday out-of-school experiences. To foster innovation competence in students, relevance can be promoted through connecting teaching with students' everyday experiences in forms of user-centred design learning and engaging in authentic activities, using open-ended tasks and real-world problems (Jonassen, 1994; Lim & Sato, 2006). It is important that students have the opportunity to engage with real-world problems in the field of study in order to have a rich and meaningful learning experience (Fasko, 2001, p. 322).

Uncertainty is the extent to which students are provided the opportunity to experience that innovative knowledge is evolving and that it is culturally and socially determined. Innovative knowledge, according to Messmann and Mulder (2014), represents the sum of all that the student must know in order to successfully navigate the innovation process. This involves teaching students how to explore, collect, analyse, and use data to ignite innovation (Dyer et al., 2009; Honebein, 1996). Students are made to understand that the process of knowledge creation occurs not only in individual contexts, but also through the interactions involved in social negotiations, collaborations, and experiences (Dyer et al., 2009; Jonassen, 1994).

Student negotiation is the extent to which the students and teacher share control of the design and management of learning activities, assessment criteria, and social norms of the classroom. By negotiating the instructional goals and objectives with the students, the teacher acknowledges the relevance of students' involvement in learning. Teachers can use students' reflections to design learning activities for innovation competence and create environments that encourage metacognition, self-analysis, regulation, reflection, and self-awareness (Ernest, 1995). In such environments, the teacher is seen by the students as a co-learner, co-researcher, and explorer as they engage in the tasks, and the teacher is resourceful and supportive of students' learning needs (Burgess & Addison, 2007; Rutland & Barlex, 2008). In this way, a safe and collaborative atmosphere is created where different students' learning approaches are valued. The literature provides strong evidence that students' innovation competence is enhanced when they are provided with opportunities to work collaboratively with each other (Burgess & Addison, 2007; Dillon et al., 2007; Halsey et al., 2006; Rutland & Barlex, 2008; Wood & Ashfield, 2008). Group work or working in teams has been demonstrated to be a relevant feature of innovation-supportive learning environments (Burgess & Addison, 2007; Rutland & Barlex, 2008).

In this current study, the CLES was adopted to evaluate students' perceptions of their classroom environments with respect to innovation competence, using selected scales from the CLES (Taylor et al., 1995; Taylor et al., 1997), namely, personal relevance, uncertainty, and student negotiation.

Below, we review relevant past studies on students' perception of their existing learning environments using the CLES instrument. To compare perceptions from prior studies with those in our own study, scores in those studies were converted to a 7-point scale, and subsequently qualitatively interpreted. Hence, converted scores between 3.5 and 4.4 indicate a medium perceived level personal relevance, uncertainty, and student negotiation scores. below 3.5 indicate a low perceived level and scores above 4.4 indicate a high perceived level.

Research on constructivist learning environments has confirmed the factorial validity and reliability of the CLES in various contexts and countries (Aldridge et al., 2000; Beck et al., 2000; Kim et al., 1999; Kwan & Wong, 2014; S. Lee & Taylor, 2001; Ozkal et al., 2009; Taylor et al., 1997). For instance, the factorial validity and reliability of the CLES were established by Taylor et al. (1997) in Western Australia, with a sample of 494 13-year-old students in 41 science classes in 13 schools. Similarly, Aldridge et al. (2000) cross-validated the CLES also in Australia with a sample of 1,081 science students in 50 classes. The CLES was validated as well in Korea (Kim et al., 1999; S. Lee & Taylor, 2001) and Taiwan (Aldridge et al., 2000), and its cultural adaptability was shown by S. Lee and Taylor (2001) in their longitudinal study in Korea. In the study by Aldridge et al. (2000), the original English version of the CLES was administered to 1,081 science students in 50 classes in Australia, while a translated Chinese version was administered to 1,879 science students in 50 classes in Taiwan. In both countries, the same factorial structure for the CLES and reasonable scale reliabilities were observed. In Singapore, Koh and Frazer (2014) used a modified version of the CLES. In their study, good factorial validity and internal consistency reliability for both the actual and preferred learning environment were found.

Topolovčan, Matijević and Dumančić (2016) examined the perceptions of eighth-grade students (n = 1,026) in primary and lower secondary education in the Republic of Croatia regarding the characteristics and frequency of constructivist learning. On a five-point scale, personal relevance (M = 3.26), uncertainty (M = 3.29) and student negotiation (M = 3.05) were perceived as present at around a medium level by the students. Nix et al. (2005) used a modified version of the CLES that they called the Integrated Science Learning Environment model to evaluate the impact of an innovative teacher development program in high school classrooms. The study reported the perceptions of 445 students taught by 5 teachers in 25 classes, and 328 students from 19 classes taught by 5 non- Integrated Science Learning Environment teachers in north Texas. On a five-point scale, the results showed a medium level of perceived personal relevance (M = 3.21), uncertainty (M = 2.61) and student negotiation (M = 2.86). Koh and Fraser (2014) studied 2,216 secondary school students in Singapore, in 82 business classes taught by preservice teachers, regarding the constructivist nature of their classroom environments. These teachers receive special training in how to create constructivist learning environments. The perceptions of the students taught by these trained teachers were compared with the perceptions of 991 secondary school students in 32 business classes taught by traditional teachers. The perceptions of students about the constructivist nature of their actual classroom environments revealed a perceived medium level of both personal relevance (M = 3.23) and student negotiation (M = 3.33), while uncertainty (M = 3.48) was slightly above a medium level. Kwan and Wong (2014) investigated secondary school students' perceptions of the constructivist nature of their learning environment in liberal studies (n = 967) in Hong Kong, and whether their perceptions were related to their critical thinking ability. The results showed high scores (on a 5-point scale) for Personal Relevance (M = 3.44), Uncertainty (M = 3.66) and Student Negotiation (M = 3.41). In general, students perceived their learning environment positively for the three variables. Spinner and Fraser (2005), using a between-groups comparison, pretest-posttest design, analysed 53 students' responses to their classroom environment, their attitudes and their conceptual development as related to mathematics education. The students in the experimental group scored Personal Relevance (M = 3.82) and Uncertainty (M = 3.55) high, whereas Student Negotiation (M = 3.23) received a medium score. For the control group students, medium scores were reported for Personal Relevance (M = 3.81), Uncertainty (M = 3.05) and Student Negotiation (M = 2.55). The results showed an increment in scores for the experimental group in comparison with the control group, thereby displaying the effectiveness of the intervention.

Overall, the different studies using the CLES show that students typically perceive their environment to be moderately constructivist in nature (e.g., around or slightly above the neutral score). Student negotiation was rated the lowest by the students in most studies, whereas uncertainty received the highest scores. The intervention studies showed an increase in scores for all variables for the treatment group. However, most of these studies were conducted in primary and secondary education; little is known about perceptions of these elements in higher education. Similarly, there has been no research that has examined the relationships between scores on CLES scales and (self-)perceptions of innovation competence specifically. This study therefore aimed to study the associations between constructivist learning environments as measured by CLES and innovation competence in the context of higher education.

2.2.3 Research questions

Building upon the reviewed literature, this study was designed to answer the following research questions:

1. How do Built Environment students perceive their own innovation competence?

2. What are students' perceptions of the existing learning environment with respect to innovation competence?
3. How do Built Environment students perceive the focus on innovation competence at the curriculum level and the relevance of teaching that aims to develop innovation competence in their major programme of study?
4. What is the association between students' perceptions of the learning environment and their perception of their own innovation competence?

2.3 Method

2.3.1 Context and sample

A survey was administered via the various schools' heads of department by email to students at eight universities of applied sciences in the Netherlands where Built Environment programs were offered. At universities of applied sciences, Built Environment departments are required to develop students' innovation competence. Therefore, innovation competence is an end goal for all students following Built Environment programs. Innovation competence is considered one of the core competences necessary for career success in the professions addressed by the Built Environment discipline. Correspondingly, several educational steps have been taken towards realizing the above objective in the various Built Environment departments.

An online questionnaire with an explanatory cover letter was emailed to a random sample of 400 year 1 to year 4 Built Environment students at the various schools. After an initial mailing, three follow-up reminder emails were sent. Overall, 130 students completed the questionnaire, on which subsequent analyses were based. Of the 130 students, 27% were female. Students' ages ranged from 17 to 37 years ($M = 21.5$, $SD = 2.49$). Students were distributed over the years of study as follows: year 1, $n = 27$; year 2, $n = 28$; year 3, $n = 32$; year 4, $n = 43$. Year of study represents the current year of study students were enrolled in at the time of completing the questionnaire.

2.3.2 Instrumentation

The questionnaire mapped students' perceptions of the learning environment with respect to innovation competence development and students' self-perceived level of innovation competence (Appendix A). Also mapped were students' perceptions of the focus and the relevance of innovation competence, as well as the association between their perceptions of the learning environment and students' self-perceived level of innovation competence. We created the items using a 7-point response format of 'strongly disagree' (1), 'disagree', somewhat disagree', ‘neither agree nor disagree’, ‘somewhat agree’, ‘agree’ and ‘strongly agree’ (7), unless described otherwise. See appendix A for the students’ survey questionnaire.

2.3.3 Innovation Competence

To measure students’ self-perceived innovation competence in order to answer research question one, six scales were compiled using previously validated scales from three different groups of authors. The scales measuring creativity, leadership and solving ambiguous problems were originally developed by Hurt et al. (1977) using US college students and public school teachers. Out of 20 original items (displaying an overall Cronbach’s alpha of 0.94), 13 items were selected for the current study (see Table 2.1). The Energy and Risk Propensity scales were based on the work of Chell and Athayde (2009) using college students in the UK (with reported Cronbach’s alphas of 0.75 and 0.58, respectively). Lastly, the items on the Creative Self-efficacy scale (which had a Cronbach’s alpha of 0.83 in their study) were taken from Tierney and Farmer (2002). See Table 2.1 below for the newly-compiled innovation competence scales.

Exploratory factor analysis on the data from the present study suggested a 6-factor solution. In this analysis, a varimax rotation was used, eigenvalues were set to 1 or higher, and factor loadings were inspected for meeting the 0.35 threshold on their expected scales and no high loadings on other scales. This solution followed the expected pattern, even though some items had to be removed for not meeting the criteria.

In the end, seven items measured creativity, with a Cronbach’s alpha of 0.90, while three items measured creative self-efficacy, with a Cronbach’s alpha of 0.83. Three items measured students’ perceptions of their leadership, with a Cronbach’s alpha of 0.77. The Energy scale was measured with seven items having a Cronbach’s alpha of 0.81. Four items measured students’ perceptions of their risk propensity, with a Cronbach’s alpha of 0.67. The Solving Ambiguous Problems scale was measured with just 2 items, with a Cronbach’s alpha of 0.79. All variables correlated significantly one with another, but the correlations were sufficiently low to justify the use of separate scales (see Table 2.5, variables 4-9, for the correlation matrix).

Table 2.1 Scale description, sample item and reference for each scale in the newly-compiled Innovation Competence measure

Scale	Description	Sample item	Reference
Creativity	Seeking new ways of doing things, imagination, inventiveness, connecting ideas, tackling and solving problems, curiosity	I seek out new ways of doing things	Hurt et al. (1977)
Leadership	Vision, organizing, managing and the ability to mobilize commitment to achieve the intended goal	I enjoy taking part in leadership responsibilities in the group I belong to	Hurt et al. (1977)
Energy	Drive, enthusiasm, motivation, hard work, persistence and commitment in engaging in innovative activities	When I'm doing something, I like to feel it has a purpose or goal	Chell and Athayde (2009)
Creative Self-efficacy	Self-belief, self-assurance, self-awareness, feelings of empowerment, social confidence about one's creative ability	I have confidence in my ability to solve problems creatively	Tierney and Farmer (2002)
Risk Propensity	A combination of risk tolerance and the ability to take calculated risks	When I make choices, I want to be as sure as possible what the future consequences will be for me. (reverse-coded)	Chell and Athayde (2009)
Solving Ambiguous Problems	Liking to solve ambiguous problems	I am challenged by unanswered questions	Hurt et al. (1977)

All items used the response alternatives of strongly agree (7); agree; somewhat agree; neither agree nor disagree; somewhat disagree; disagree and strongly disagree (1).

2.3.4 Learning Environment

For the purpose of answering research question two, three constructs were selected from the CLES instrument. The Personal Relevance, Uncertainty and Student Negotiation scales from the Constructivist Learning Environment Survey (CLES; Taylor et al., 1997) were used to assess the explicitness of and focus on learning activities in the classroom environment that were supportive of innovation competence (see Table 2.2). Taylor et al. (1997) reported Cronbach's alphas of above 0.70 for all of the scales in their study. A number of items were selected and reframed to fit the purpose and the context of our research. Two new items were added to the

Personal Relevance scale. Exploratory factor analysis (EFA) was conducted to analyse construct validity. Principal axis factoring (PAF) and oblimin rotation were used. Because three scales were expected, the analysis was constrained to three factors. All items loaded meaningfully on their respective scales.

Table 2.2 Scale description, sample item and reference for each scale in the newly compiled Learning Environment measure

Scale	Description	Sample item	Reference
Personal Relevance	Connection of teaching and learning to students' everyday experience or solving authentic tasks across domains	In my studies within my major, I learn about the world beyond the work-field of Built Environment in order to become innovative	Taylor et al. (1997)
Uncertainty	Opportunities provided for experiencing science as evolving, culturally and socially determined.	In my studies within my major, students learn about the different innovative techniques used by people in other fields	Taylor et al. (1997)
Student Negotiation	The opportunity the teacher provides to students to discuss and share views about innovative problem solving with each other	In my studies within my major, students discuss how to solve problems innovatively with other students	Taylor et al. (1997)

All items used the response alternatives of strongly agree (7); agree; somewhat agree; neither agree nor disagree; somewhat disagree; disagree and strongly disagree (1).

Personal Relevance in our study comprised four items, with a Cronbach's alpha of 0.87. *Uncertainty* consisted of five items, with a Cronbach alpha of 0.92. *Student Negotiation* consisted of just two items, with a Cronbach's alpha of 0.85. As can be seen in Table 2.5, the three CLES scales (variables 1-3 in the table) were statistically significantly correlated with each other, although to a low enough level that they can be considered as independent scales.

2.3.5 Relevance of innovation competence: focus on innovation competence at the curriculum level and relevance of teaching for innovation competence

Previous research has revealed that educators have made serious efforts to stimulate innovation competence by focusing on developing students' innovation competence through teaching (Beghetto & Kaufman, 2013). For this reason, we sought to know via research question 3 how students perceived their teachers' focus on innovation competence in their school and its relevance.

The scale related to *focus on innovation competence at the curriculum level* consisted of four items, created to measure a school's explicit focus on innovation competence at the school/curriculum level. Reliability in terms of Cronbach's alpha was 0.90. A sample item in the scale was, 'At my school, innovation competence is an end goal'. Factor analysis revealed a one-factor solution, accounting for approximately 74% of the common factor variance, with all 4 items loading meaningfully on the factor.

To measure perceptions of the *relevance of teaching for innovation competence*, students were asked to respond to one item, with response options ranging from very irrelevant (1) to very relevant (7). The item asked whether they considered being taught about how to become innovative relevant. Students were also asked to indicate in a single binary item (yes or no) if they were explicitly being taught by their teachers to become innovative in their major course of studies. Respondents who answered yes were asked to further specify the subject/course/module name and study year of the course. This approach has also been used by other researchers investigating innovation competence in the curriculum (Adams, 2013; Aish, 2014; Shaheen, 2011).

2.3.6 Data analysis

The data collected from students through the questionnaires were organized, presented in tables and then analysed statistically by calculating means and standard deviations for the purpose of answering research questions 1 to 3. Correlations and regression analysis were conducted for the purpose of answering research question 4. In the regression analyses, the six self-perceived competencies were entered as dependent variables and the learning environment variables as the independent variables. In addition, we also computed an overall innovation competence score as the average of the six specific competencies, and this variable was also used in the regression analyses. Correlations were interpreted as follows (Cohen, 1988): $|r| = .10$ to .29 as small; $|r| = .30$ to .49 as medium; $|r| = .50$ to 1.0 as large.

2.4 Results

2.4.1 Students' perception of their own innovation competence (research question 1)

The results related to students' perception of their own innovation competence are categorized under the six separate constructs to which the scales refer: creativity, leadership, energy, creative self-efficacy, risk propensity and solving ambiguous problems.

The results as presented in Table 2.3 show that students on average perceived their innovation competence as reasonably high on all six scales. However, students reported a somewhat higher score for energy, creativity and creative self-efficacy, than for solving ambiguous problems, risk propensity and leadership. The standard deviations suggested considerable differences on each aspect between students.

2

Table 2.3 Average scale means and standard deviations of scores for Innovation Competence

	Creativity	Leadership	Energy	Creative Self-efficacy	Risk Propensity	Solving Ambiguous Problems
M	5.51	4.99	5.65	5.11	4.79	4.77
SD	.86	1.07	.81	1.07	1.06	1.26

N = 130.

2.4.2 Students' perceptions of the learning environment (research question 2)

The results regarding students' perceptions of the learning environment are presented in Table 2.4 show that students on average perceived their learning environment as *moderately* constructivist. All scores ranged around the midpoint of 4 on a scale of 1 to 7, with personal relevance rated as the lowest, while student negotiation was rated the highest.

Table 2.4 Average scale means and standard deviations of scores for the Perceived Learning Environment

	Personal Relevance	Uncertainty	Student Negotiation
M	3.83	4.02	4.15
SD	1.361	1.437	1.585

N = 130.

2.4.3 Students' perceptions of the relevance of teaching for innovation competence development (research question 3)

The results regarding students' perceptions of the focus on innovation competence at the school/curriculum level, ($M = 4.17$, $SD = 1.49$) showed a *moderate* perceived focus on innovation competence, on a scale of 1 to 7. Regarding the question as to whether *teaching students to become innovative is relevant*, students reported a view of it as *somewhat relevant*, on average ($M = 4.69$, $SD = 1.40$). Students were also asked to indicate on a single item scale if they were intentionally taught by their teachers to become innovative in their major course (*yes or no*). Of the 130 participants, 51 students (39.2%) indicated that there was indeed an explicit teaching focus on development of innovation competence, whereas 79 (60.8%) indicated NO explicit teaching focus. Of the 51 students who indicated an explicit teaching focus on innovation competence, only 27 of them further specified a course or module that had an explicit focus on students' innovation competence development at their school. Some examples of modules specified were a 3rd year architectural module focused on developing concepts for a zero-energy commercial building and a 2nd year renovation project module in which students were asked to design new functions and building methods. Other examples mentioned by students were broad subject areas such as structural design, building physics and building technology.

2.4.4 The association between perceptions of the learning environment and perceived innovation competence (research question 4)

We used a multiple regression analysis to investigate the relationships between the Perceived Learning Environment scales (Personal Relevance, Uncertainty, Student Negotiation) and the self-perceived Innovation Competence scales (Creativity, Leadership, Energy, Creative Self-efficacy, Risk Propensity and Solving Ambiguous Problems). The perceived level of focus on innovation competence at the school level and the relevance of teaching for innovation competence development were also tested as predictors of self-perceived innovation competence. Firstly, we discuss the results of the correlation analysis presented in Table 2.5.

Table 2.5 Bivariate correlation matrix for the Learning Environment, Innovation Competence (IC), and Focus and Relevance scales

Scale	1	2	3	4	5	6	7	8	9	10	11
1. Personal relevance											
2. Uncertainty	.77**										
3. Student negotiation	.68**	.79**									
4. Creativity	.07	.13	.21*								
5. Leadership	.28**	.16	.27**	.49**							
6. Energy	.17*	.17	.13	.62**	.45**						
7. Creative self-efficacy	.10	.121	.18*	,73**	,50**	,48**					
8. Risk propensity	.15	.22*	.16	.28**	.23**	.46**	.30**				
9. Ambiguous problem-solving	.23*	.14	.21*	.52**	.42**	.44**	.51**	.19*			
10. Focus on IC at school	.63**	.58**	.58**	.03	.24**	.16	.06	.23**	.13		
11. Relevance of IC teaching	-.06	.01	-.06	-.11	-.08	-.14	-.07	-.04	-.09	-.06	

** $p < 0.05$; ** $p < 0.01$. N = 130.*

As can be seen in Table 2.5, scores on all six Innovation Competence scales were positively and statistically significantly correlated with one or more of the three constructivist learning environment variables.

2

In order to determine the joint and unique predictive contribution of the learning environment, focus and relevance variables to students' total innovation competence and its individual components, seven stepwise multiple regression analyses were conducted. The first analysis focused on students' combined innovation competence (average of 6 competence), while the second to the seventh steps calculated the joint effects of each learning environment, focus and relevance variable on each of students' separate innovation competences.

The first step revealed a significant relationship for *student negotiation*, which accounted for 5.7% (5.0% adjusted) of the variance in *students' total innovation competence scores.* This means that the more students perceived negotiation in their learning environment, the more they perceived themselves overall as having innovation competence. The second analysis indicated a significant relationship for *student negotiation*, which accounted for 4.5% (3.7% adjusted) of the variance in *creativity* scores. Thus, the more students perceived negotiation in their learning environment, the more they perceived themselves overall as creative. The third analysis indicated a significant association for *personal relevance*, which accounted for 7.8% (7.1% adjusted) of the variance in *leadership* scores. The more students perceived learning to be personally relevant in their learning environment, the more they perceived themselves overall to take a leadership role. The fourth analysis indicated a significant association for *personal relevance*, which accounted for 3.0% (2.2% adjusted) of the variance in *energy* scores. This means that the more students perceived learning to be personally relevant in their learning environment, the more they perceived themselves to expend energy in learning. The fifth analysis indicated a significant relationship for *student negotiation*, which accounted for 3.3% (2.5% adjusted) of the variance in *creative self-efficacy* scores. Hence, the more students perceived negotiation in their learning environment, the higher they rated their creative self-efficacy. The sixth analysis indicated a significant association for *focus on innovation competence at school*, which accounted for 5.3% (4.6% adjusted) of the variance in *risk propensity* scores. The more students perceived there to be a focus on innovation competence development in their learning environment, the more willing they were to take risks. Finally, the seventh analysis indicated a significant relationship for *personal relevance*, which accounted for 5.1% (4.3% adjusted) of the variance in scores for solving *ambiguous problems.* The more students perceived learning to be personally relevant in their learning environment, the more they perceived themselves overall as competent in solving ambiguous problems. All reported associations were statistically significant at the 0.05 level.

2.5 Discussion and conclusion

The main goal of this study was to map students' perceptions of the extent to which Built Environments' curricula were directed towards and resulted in the development of innovation competence, by measuring students' self-perceived innovation competence, the relevance of teaching for innovation competence and perceptions of the learning environment. The results showed that students perceived that the learning environments at the universities of applied sciences were only to some degree directed towards development of students' innovation competence, which may indicate that if teachers were concerned with this competence, it may have been in a rather implicit fashion. Although students perceived learning to become innovative as somewhat relevant, and rated their innovation competence relatively high, their perceptions of the learning environment showed a somewhat lower perception of the personal relevance of the teaching and learning activities in their school environments. These results suggest that the presence and role of constructivist elements in the existing learning environments can be strengthened and that universities of applied sciences can potentially enhance their students' innovation competence by implementing constructivist learning environments principles more explicitly.

The results showed that students perceived themselves on average to be sufficiently competent in accomplishing innovation-related tasks; higher scores were reported for creativity, leadership, energy and creative self-efficacy, but lower scores for risk propensity and ability to solve ambiguous problems. High scores on the innovation competence scales, according to Chell and Athayde (2009), should represents students' intentions to become future innovators. The relatively lower scores for risk propensity in our study could be explained by a lack of formal teaching mechanisms for risk propensity in the domains of Built Environment education. Chell and Athayde (2009) concluded that the lack of teaching risk propensity in school would most likely reflect students' interest and intelligence and/or their socio-economic background. It is worth mentioning that risk propensity was a weak scale in the original instrument of Chell and Athayde (2009), with an alpha coefficient of 0.58. The same applied to our study, where risk propensity was also a relatively weak scale, with a Cronbach's alpha of 0.67. Risk propensity has many dimensions (Chell & Athayde, 2009); hence, it is suggested that education should focus on these different dimensions, which include thrill seeking, avoiding risk, and taking calculated risks. Taking calculated risks involves recognizing inherent risks in what one does, but also being able to take relevant steps to reduce those risks. Risk adaptors or absorbers recognize the risks in what they do, but either naturally or through training learn to bear those risks. Considering the complexity of risk propensity and its typologies in educational settings, teaching students how to take, bear, analyse and absorb risk is very relevant, but difficult to realize. Further research could be conducted to gain understanding into what really constitutes risk propensity and its teaching.

In a way, this research re-establishes and joins the array of studies that have confirmed the effectiveness of using students' views to understand learning environments (den Brok et al., 2006; Fraser, 2007; Koh & Fraser, 2014; Kwan & Wong, 2014; Nix et al., 2005). Students generally were moderately positive about the constructivist nature of the learning environment for innovation competence in their schools with regard to personal relevance, uncertainty and student negotiation, thereby replicating the findings of prior studies (Koh & Fraser, 2014; Kwan & Wong, 2014; Nix et al., 2005; Spinner & Fraser, 2005; Topolovčan et al., 2016). The highest score reported in this study was for student negotiation, which did not align with the results of past studies. Student negotiation refers to the opportunities teachers provided to students to discuss and share views about innovative problem-solving strategies with each other. One possible explanation for this high score for student negotiation could be the design studio educational approach that is peculiar to this domain. The design studio educational approach is characterised by a high level of focus on student-to-student communication and reflective practices (Schön, 1987). This could mean that students in this domain consider it normal to discuss or negotiate freely one with another. It might not be surprising therefore, that participants in this study scored higher on student negotiation than participants in studies in other countries, suggesting that teachers provide opportunity for discussion to students in the design and management of learning activities. Another potential explanation is the fact that students in our study were enrolled in higher education, whereas most other studies were done in secondary education. It might be expected that students in higher education are given more responsibility for their learning process, as well as in the classroom.

In this study, uncertainty was rated relatively high, which is consistent with prior studies (Koh & Fraser, 2014; Kwan & Wong, 2014; Nix et al., 2005; Topolovčan et al., 2016). Interestingly, the students in our study scored personal relevance *lowest*, which is contrary to the findings of Kwan and Wong (2014), Kim et al. (1999) and Topolovčan et al. (2016), but consistent with the findings of Koh and Fraser (2014). The differences could be attributed to the differences in educational contexts (secondary versus higher education). University students are often older and therefore may be more conscious and more realistic about their perceptions of their learning environments compared to primary and secondary education students. This may suggest the need for further studies of these variables in the context of higher education.

2.6 Understanding the association between innovation competence and learning environment

There was a statistically significant correlation, as expected, between scores for each of the constructivist learning environment variables (personal relevance, uncertainty, student negotiation) and each of the six innovation competence variables. Multiple regression analyses showed that student negotiation was the only significant predictor of students' overall perceived innovation competence. Our study suggests that when teachers involve students in the design and management of learning, a learning environment will be created that supports students' creativity and innovative thinking, rather than constraining it. Unfortunately, no other studies have looked at this relation in the context of higher education. Therefore, comparing our results with past studies is not possible.

2.7 Limitations

There were some limitations in the present study that should be addressed in future research. First, this study was limited in the sense that it only looked at a set of factors that were proposed to be linked with innovation competence and its teaching. However, as found in other studies, innovation competence is sometimes affected by other variables, such as personality traits (Fisher et al., 2011), the physical environment, and teachers' teaching style. While this study did not examine the relationships between those variables and innovation competence, future studies could examine those relationships further.

Second, although our findings are in line with previous studies about how individuals perceive their innovative ability in general (Chell & Athayde, 2009; Dyer et al., 2009; Hurt et al., 1977; Tierney & Farmer, 2002), it says very little about the actual level of mastery, as students may over- or under-estimate themselves. To understand whether Built Environment students have developed innovation competence, further studies are needed. These studies should include, besides elements that were already part of the present study, validating the construct of innovation competencies by using larger sample sizes and developing design principles for creating teaching interventions intentionally dedicated to the development of innovation competence.

Finally, the image that emerges in this study is one-sided, because the results concentrate solely on students' perceptions. Teachers' views are still unknown. Therefore, follow-up studies mapping teachers' perceptions will augment and provide a more comprehensive picture of the state of affairs regarding innovation competence instruction.

2

2.8 Recommendations

For the improvement of innovation competence development in the Built Environment engineering curriculum, the following actions are recommended, based on the results of this study. First, the low scores for personal relevance compared to previous studies using the CLES in primary and secondary education suggest that more attention is needed for this dimension of the learning environment. This result requires teaching and learning to be better connected with students' everyday out-of-school experiences by engaging students in authentic activities, using open-ended tasks and using real-world problems (Jonassen, 1994; Lim & Sato, 2006).

Second, more explicit focus on innovation competence is needed, as can be derived from students' perceptions of the focus on innovation competence at the curriculum/school level, where approximately 61% of the respondents perceived no explicit focus on innovation competence in their curriculum. A portion of the curriculum should intentionally be dedicated to the development of students' innovation competence. This approach would help to consciously direct teaching to the development of students' innovative mindset and problem-solving in the context of discipline-based curricula. This approach is often avoided by educators due to the significant volume of discipline-specific knowledge to be taught, and educators' difficulties in integrating competencies into the engineering curriculum. However, previous studies (e.g., Swartz & Parks, 1994) have demonstrated the effectiveness of such an approach.

3

Teaching for innovation competence in higher education Built Environment engineering classrooms: Teachers' beliefs and perceptions of the learning environment

Chapter 2 established the perceptions of students regarding the extent to which the existing learning environments were directed towards innovation competence and students' rating of their own innovation competence. Chapter 3 proceeds to investigate teachers' beliefs regarding innovation competence relevance, creative self-efficacy and perceptions of the existing learning environment related to innovation competence instruction practices. The chapter also asks whether differences exist between students' and teachers' perceptions regarding the presence of instruction focused on innovation competence.[2]

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[2] This chapter is based on: Ovbiagbonhia, A. R., Kollöffel, B., & den Brok, P. (2020). Teaching for innovation competence in higher education Built Environment engineering classrooms: Teachers' beliefs and perceptions of the learning environment. *European Journal of Engineering Education*, 45(6), 917-936. https://doi.org/10.1080/03043797.2020.1784097.

Abstract

In this study we investigated teachers' beliefs about innovation competence relevance and their creative self-efficacy and compared teachers' and students' perceptions of the learning environment in the Built Environment engineering educational domain. In total, 94 teachers participated in this study by completing a questionnaire. Teachers perceived their creative self-efficacy to be high and the learning environment in their classrooms to be supportive of innovation competence. However, only a minority of the teachers considered teaching for innovation competence relevant; most teachers perceived a focus on innovation competence in the curriculum as neutral. Multiple regression analyses showed that teachers' creative self-efficacy beliefs significantly predicted their perception of personal relevance. Similarly, perceived focus on innovation competence in the curriculum significantly predicted perceived uncertainty, while creative self-efficacy significantly predicted perceived knowledge-building through teacher–student and student–student negotiation. Findings of the study are discussed with respect to developing students' innovation competence in the Built Environment educational domain.

3.1 Introduction

Educational systems in many countries aim to develop their students' innovation competence (Beghetto & Kaufman, 2013; Chan & Yuen, 2014; Craft, 2011; K. Robinson, 2011; Wagner, 2010), because of its importance for economic growth. The competence to innovate, which includes creativity, is considered central to many higher education domains and is defined as a core competence for the 21st-century engineer (Beghetto & Kaufman, 2013; Chan & Yuen, 2014; Craft, 2011; K. Robinson, 2011; Wagner, 2010). As in other higher education domains, innovation competence is an important learning goal in the Built Environment engineering domain. However, what is meant by the term 'innovation competence' is not always clear to the teacher, as many definitions have been reported in the literature (e.g., M. Robinson, 2001; Sawyer, 2012; Sefton-Green & Sinker, 2000). In the present study, innovation competence is the competence to develop creative ideas for products, services, procedures, theories, and strategies that are useful or meaningful to the intended audience, and that can be implemented successfully (Tidd & Bessant 2009; M. A. West & Farr, 1990). The Built Environment domain in the present study refers to departments and areas of expertise such as architectural engineering, building engineering, building management, civil engineering, and landscape and urban planning.

Innovation competence (IC) is a complex competence consisting of separate, at times overlapping competences, which altogether can be regarded as innovation competence: creativity, leadership ability, energy, creative self-efficacy, risk propensity and solving ambiguous problems (Chell & Athayde, 2009; Hurt et al., 1977; Tierney & Farmer, 2002). As was explained in more detail in Chapter 2, creativity, according to Antonietti, Colombo and Pizzingrilli (2011), is an integrated process of widening, connecting, and restructuring. Leadership entails having a clear vision of the end goal, networking, collaborating, mobilizing, organizational ability, and convincing other experts in order to achieve the goal (Dyer et al., 2009). To complete any innovation task, persistence, proactive behaviour and drive are required (Chell & Athayde, 2009). Vigour, commitment and motivation are also required (Hunter et al., 2012), all of which are inseparable components of energy. Innovative individuals have self-confidence and beliefs about their creative abilities. Creative self-efficacy has been linked to innovative behaviour in individuals (Tierney & Farmer, 2011; Wang et al., 2013). Problems for which an innovative solution is required are often ambiguous, complex and devoid of clear answers. Therefore, innovation requires taking calculated risks (Tabak & Barr, 1999). Innovators are individuals willing to bring about change within a complex and ambiguous network of problems (Hurt et al., 1977; Keller, 2012). Therefore, innovation competence could be expressed as one's inclination to be challenged by unanswered questions, ambiguities and unresolved problems (Keller, 2012).

Innovation competence is valued and is one of the most-often stated student learning goals in university curricula in a range of educational domains (Beghetto & Kaufman, 2013; Chan & Yuen, 2014; Craft, 2011; K. Robinson, 2011; Wagner, 2010). Yet, observation of teachers' classroom practices often reveals disappointing results, and students often report insufficient focus on innovation competence by their teachers. For instance, McLellan and Nicholl (2012) explored whether the climate in Design and Technology lessons was perceived as conducive for IC development. They reported that teachers felt that their learning activities and tasks were challenging and meaningful and that they granted enough freedom to their students. However, students' responses revealed the opposite. Students felt that their tasks were not challenging, that they had limited freedom, and that they were supported only to a limited degree in realizing their design ideas. Similarly, Ovbiagbonhia et al. (2019) investigated 130 students' perceptions of education for innovation competence at eight universities of applied sciences, in the Built Environment domain. The results showed that, according to the students, their teachers in their major program did not explicitly focus on developing innovation competence and that the learning environment in Built Environment aimed at innovation competence only to a limited degree. Students reported limited engagement in personally relevant tasks, and limited opportunities for experiencing science as evolving, culturally and socially determined. Students also perceived little negotiation with the teacher over the design and management of learning activities, assessment criteria, and social norms of the classroom – all of which are elements considered conducive to innovation competence supportive teaching (Ovbiagbonhia et al., 2019). Hence, students do not seem to perceive the learning environment in their classrooms as conducive for innovation competence development. Although students' perceptions reveal an interesting picture of the perceived learning environment for stimulating innovation competence, they represent only part of the picture, as teachers' perceptions are still missing at the higher education level. Past research on the learning environment in various educational domains has shown considerable differences between teachers' and students' views (see, e.g., Bell & Aldridge, 2014; Martin-Dunlop & Fraser, 2008).

The results of these observational studies and studies on student perceptions suggest that teachers' focus on IC in the classroom might be limited. There is evidence in the literature that the perceptions, beliefs and values of teachers affect their teaching practice (Ajzen, 1991); hence, it is important to further investigate these beliefs. Davies et al. (2013), in their systematic literature review on teachers' roles and what is necessary for promoting creativity, concluded that teachers need to have a positive attitude towards innovation and need to feel confident about their own creativity. This raises two questions. First of all, are teachers more positive than students about IC-conducive classroom practices, given the results of previous learning environment studies that show that teachers are usually more positive about their classroom practice? Assuming that teacher perceptions might show a similar overall picture, the second question is: is it possible that teachers pay little attention to innovation competence instruction, despite its relevance, and why is that? To what degree do their beliefs, for example, about the importance of innovation competence, play a role in this?

Unfortunately, teachers' beliefs about the relevance of innovation competence and their perceptions of classroom practices aimed at developing innovation competence in students have not received much research attention, particularly not in the Built Environment engineering education literature (Beghetto & Kaufman, 2014; Bereczki & Kárpáti, 2017; C. Richardson & Mishra, 2018). Whether teachers really foster innovation competence in practice and what factors affect them in trying to do so are still unknown. Therefore, understanding teachers' beliefs and perceptions of the learning environment for innovation competence education is an essential issue, with practical significance for the identification, development, and evaluation of innovation competence interventions in schools (Beghetto & Kaufman, 2014; Bereczki & Kárpáti, 2017). Understanding the various factors that might assist or hinder teachers in developing students' innovation competence are also important areas of study (C. Richardson & Mishra, 2018; Tolbert & Daly, 2013). In this way, a foundation for the improvement of professional preparation and training directed at supporting teachers in creating an innovation competence supportive learning environment can be provided (Diakidoy & Kanari, 1999). This study aims to fill this gap in the literature by mapping teachers' self-beliefs and their perceptions of the existing learning environments aimed at innovation competence development, as well as investigating the association between them.

3.2 Conceptual framework

This study is based upon learning environment research, in which the importance of perceptions is endorsed (Fraser, 2012), and the assumption that these perceptions are partly determined by the beliefs of teachers. In the following sections, both aspects will be described.

A conceptual framework that can be used for studying teachers' perceptions about innovation competence supportive environments was proposed by Andiliou and Murphy (2010) in their review of the literature before 2010, and was further developed by Bereczki and Kárpáti (2017) in their review of the literature between 2010 and 2015. The frameworks capture teachers' beliefs about creativity and their perceptions about the learning environment. Research has revealed that certain teacher characteristics, such as teachers' own creative self-efficacy beliefs, may influence their innovation competence instruction (Mullet et al., 2016; V. Richardson, 1996). Based on these frameworks and given the fact that not much is known about these variables in the Built Environment domain and in higher education, the framework for the current study was created, based on the insights gained from the work by Andiliou and Murphy (2010) and Bereczki and Kárpáti (2017); see Figure 3.1.

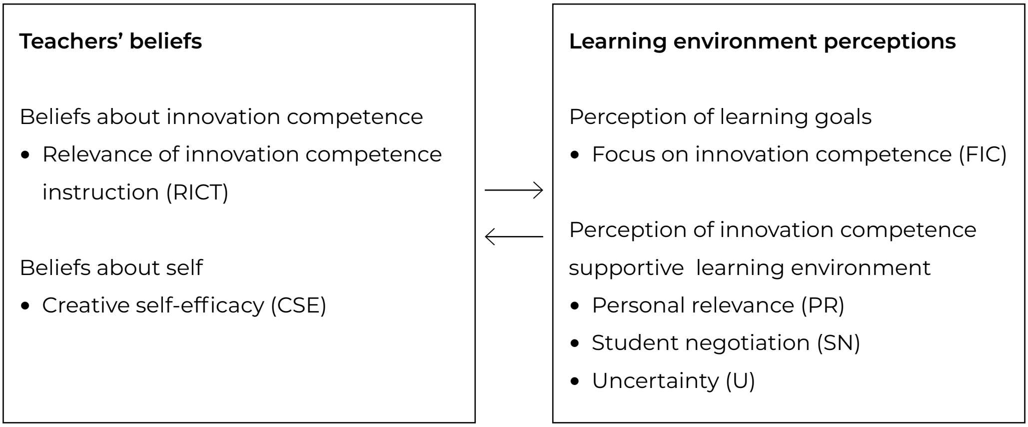

Figure 3.1 Factors affecting innovation competence supportive learning environments in higher education

3.2.1 Teachers' beliefs

Teachers' beliefs concern the ideas teachers hold about the relevance of innovation competence instruction and their own creative self-efficacy.

Beliefs about the relevance of innovation competence instruction (RICT) - Enhancing students' innovation competence requires a teacher who is capable of activating students' innovative attitude and mindset to innovate (Craft, 2005). Such a teacher believes in the relevance of improving students' innovation competence and desires to make students become innovative through their teaching (Runco, 2007). Teachers' beliefs play a major role in their decision-making about curriculum and instructional tasks (Beck et al., 2000; Berliner, 2005; Saylan et al., 2016). Therefore, educational researchers have advocated the need for a closer examination and direct study of the relationship between teacher beliefs and classroom practice (Craft, 2005; Runco, 2007). For instance, Kampylis and Valtanen's (2010) study of 132 Greek in-service and prospective secondary education teachers investigated how these teachers conceived of creativity. They found that 84% of teachers believed that creativity is a key factor for personal and social progress. Park et al. (2006) used an open-ended questionnaire and interview to investigate changes in 32 Korean secondary education science teachers' perceptions of creativity and science teaching after participating in an overseas professional development program. The study revealed teachers' support for the importance of creativity. They reported teachers' growing awareness that creativity can be expressed by every student; creativity can be enhanced; science has a much wider range of activities that foster creativity; and creativity-centred science teaching can be implemented in Korea. The contents of the professional program that promoted these changes in teachers' beliefs and attitudes included hands-on creativity activities, observation of creativity-centred classrooms, and discussion with other teachers. They reported that these perception-related changes were reflected in teaching practices. Similarly, a survey study by Rubenstein et al. (2013), asking 650 graduate degree teachers about their perceptions of factors that allow for creative teaching, indicated that teachers assigned value to developing students' innovation competence.

Beliefs about creative self-efficacy (CSE) - There is evidence in the literature that teachers' beliefs about their own roles, such as their creative self-efficacy, impact their classroom practice and the value they place on developing students' innovation competence (Lissmann, 2005; Rubenstein et al., 2013). Tierney and Farmer (2002) defined creative self-efficacy "as the belief one has in the ability to produce creative outcomes" (p. 1138), which is strongly aligned with Bandura's (1986) general description of self-efficacy. Previous research has shown that negative self-efficacy beliefs have a marked negative impact on innovative outputs and that more emphasis must be placed on reducing teachers' negative creative self-efficacy (Beghetto et al., 2011). Teachers have also expressed overall high levels of creative self-efficacy in promoting creativity in their students (Al-Nouh et al., 2014; Rubenstein et al., 2013).

The aforementioned studies demonstrated that teachers' beliefs concerning IC indeed play a major role in making decisions about their teaching (J. C. K. Lee et al., 2013). Unfortunately, this conclusion only represents findings for teachers in lower education, and says little about teachers in higher education, as to our knowledge, no such study has been reported. Whether teachers in higher education, particularly in Built Environment education, believe that increasing their students' innovation competence through teaching is relevant and believe in their ability to foster this competence remains unknown.

3.2.2 Perceptions of the innovation competence learning environment

A context or specific setting (social and cultural) that is intentionally developed to support learning is often referred to as a learning environment, milieu, or climate (Fraser, 2012). The learning environment includes the psychological factors, classroom teaching, and the physical factors in any place where learning occurs, including virtual and non-traditional spaces (Fraser, 2012). The innovation competence components defined in the introduction section (such as leadership, creativity, energy, and so on) are necessary to ensure student mastery of innovation skills. Curriculum, instruction, and the learning environment must be aligned to produce a support system that will lead to these outcomes. Innovation competence are often generic and tacit in nature, and they require distributed learning (Beghetto & Kaufman, 2014; Park et al., 2006; Sawyer, 2006; Son & Simon, 2011; Victor, 2016). Distributed learning as used here means that the learning activities are distributed over a long period of time, so that the student must integrate the various separated parts of the material into a unique entity. The development of such learning activities may require an orchestrated and coherent learning environment at the curricular level (J. C. K. Lee et al., 2013). To create an innovation competence supportive learning environment, a key aspect is to recognize innovation competence as a student learning goal that should be supported in education (Chan & Yuen, 2014; K. Robinson, 2011; Wagner, 2010). Research has suggested that improving students' innovation competence is best achieved through the creation of innovation competence supportive learning environments (Beghetto & Kaufman, 2014; Jeffrey, 2006; C. Richardson & Mishra, 2018).

Focus on teaching for innovation competence (FIC) – is the degree to which teachers deliberately translate the innovation competence learning goals into classroom teaching and assessment activities. Although the curriculum can be an intended opportunity for fostering students' innovation competence (Park et al., 2006), it is relevant to understand how teachers perceive the intended curriculum, as they are the main vehicle for realizing innovation competence in classroom practice. Previous research in this area has suggested that teachers perceive that the nature of the school's curriculum, in terms of the (lack of) emphasis on teaching for innovation competence, is one of the main hindrances to innovation competence instruction (Aish, 2014; Al-Nouh et al., 2014; Cheng, 2010; Kampylis & Valtanen, 2010; Scott, 2015; Shaheen, 2011). While this may be the reality in primary and secondary education, the question is whether the situation in higher education differs. Is innovation competence a teaching focus for teachers in higher education? It is unknown whether teachers really foster innovation competence in higher educational domains and how they perceive the curricula for innovation competence in higher education. Understanding teachers' perceptions of the role of innovation competence in the curricula, knowing whether they actually foster this innovation competence through teaching, and understanding the relationship between teachers' beliefs, perceptions and schools' focus on innovation competence are relevant for both educational policy and practice.

An innovation competence-supportive learning environment is defined as an environment designed specifically to promote the learning of innovation competence, which, according to Jeffrey

(2006) is characterized by focusing the content on personal relevance, by student ownership of knowledge and control of learning processes and by emphasizing innovation. Regarding the learning environment, many researchers and educational practitioners have advocated that teachers' perceptions of the classroom environment play a fundamental role in fostering innovation competence (e.g., Bassett, 2004; Davis & Rimm, 1998; Sternberg & Williams, 1996). To create an innovation competence supportive learning environment, three essential strategies are often employed (R. E. West et al., 2012; Wright et al., 2013). First, learners are engaged in solving authentic tasks. Authentic tasks are "real world" or contextualized tasks that are personally relevant or interesting to the learner (Duderstadt, 2008; Sheppard et al., 2009; R. E. West et al., 2012). Second, learners are encouraged to actively construct their understanding and create their own representations, instead of receiving processed information from a teacher (Crawley et al., 2007; Dyer et al., 2009; Wright et al., 2013). Third, learners are given the opportunity to engage in discussion, collaboration, and reflection (Dyer et al., 2009; Grasso & Burkins, 2009; Sawyer, 2006; Wright et al., 2013). In order for the students to practice innovation competence in these authentic circumstances, it is necessary that the learning environment satisfy the above-mentioned parameters. The constructivist learning environment survey (CLES) measures these parameters – personal relevance, uncertainty and student negotiation - and has been used by various researchers in different domains to measure perceptions of the extent to which these parameters are met in classrooms (Fraser, 2012; Taylor et al., 1997). The current study is the first to evaluate teachers' perceptions of innovation competence supportive learning environments using the CLES in Built Environment engineering education. In order to gain a complete picture of the existing innovation competence supportive learning environments in the Built Environment domain, teachers' and students' perceptions of the innovation competence supportive learning environments will also be compared.

Below, we briefly discuss some relevant components of the CLES emphasized in the present study. Subsequently, we will discuss some prior learning environment studies that have used CLES. Finally, we will discuss empirical findings and insights that have been obtained with this instrument in prior studies.

Personal relevance refers to the connectivity of teaching and learning with students' everyday out-of-school experiences. The connection of teaching and learning with students' everyday experiences is usually achieved through a learner-centred design for learning, using multiple perspectives for knowledge and concept-forming, and engaging students in authentic learning activities, using open-ended tasks and real-world problems (Jonassen, 1994). It is also important to provide opportunities for students to engage in real-world problems in the field of study and thereby have a rich and meaningful learning experience (Fasko, 2001, p. 322).

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Uncertainty refers to students' awareness, brought about through teaching, that innovative knowledge is evolving, and is culturally and socially determined. Uncertainty involves teaching students how to use primary data to ignite innovation (Dyer et al., 2009; Honebein, 1996). Through uncertainty-related teaching, students learn that the process of knowledge creation occurs not only in individual contexts, but also through the interaction between social negotiations, collaborations and experiences (Dyer et al., 2009; Jonassen, 1994). There is strong evidence from the literature that students' innovation competence could be enhanced when they are provided opportunities to work collaboratively with each other (Burgess & Addison, 2007; Dillon et al., 2007; Halsey et al., 2006; Rutland & Barlex, 2008). Working in groups or in teams has been linked with innovation supportive learning environments (Burgess & Addison, 2007; Rutland & Barlex, 2008).

Student negotiation refers to the opportunity provided to students to discuss and share innovative problem solving strategies with each other. By providing students with opportunities to discuss the learning activities, instructional goal and objectives, the teacher acknowledges the relevance of students' involvement in learning and knowledge sharing. The output of shared control is input for the design of learning activities for innovation competence and for the creation of an environment that encourages metacognition, self-analysis, regulation, reflection and self-awareness (Ernest, 1995). In such environments, the students see the teacher as co-learner, co-researcher, explorer and resourceful partner, and as supportive of students' learning needs (Burgess & Addison, 2007; Rutland & Barlex, 2008).

Overall, research on learning environments has confirmed the quality of the CLES in various contexts and countries (Taylor et al., 1997; see also Aldridge et al., 2000; Beck et al., 2000; Kim et al., 1999; Kwan & Wong, 2014; S. Lee & Taylor, 2001; Ozkal et al., 2009). To compare perceptions from prior studies with those in our own study, scores in those studies were converted to a 7-point scale, and subsequently qualitatively interpreted. Hence, converted scores between 3.5 and 4.4 indicate neutral perceptions, scores below 3.5 indicate negative perceptions and scores above 4.4 indicate positive perceptions.

Beck et al. (2000) studied 203 teachers who differed in their backgrounds, with the aim of identifying the factors influencing K-12 science teachers' implementation of constructivism in their classrooms, using an open-ended questionnaire and the CLES. In general, teachers' perceptions of teaching for personal relevance were positive, although teachers with bachelor's and master's degrees had more positive attitudes towards teaching for personal relevance than teachers with doctoral degrees.

Saylan, Armağan and Bektaş (2016) investigated the relationship between pre-service science teachers' (n = 531) epistemological beliefs (beliefs about teaching, learning and knowledge) and perceptions of a constructivist learning environment at seven Turkish public universities. Teachers perceived personal relevance and uncertainty as very positive and student negotiation as positive. The results also showed that the more sophisticated epistemological beliefs the participants had, the more constructivist they preferred the learning environment to be.

Savasci and Berlin (2012) used a mixed method research approach and studied four science teachers (from a public and a private high school), investigating their beliefs and classroom practices as related to constructivism and factors that influenced their classroom practice. The results suggested that the teachers embraced constructivism, but classroom observations did not confirm implementation of these beliefs for three of the four teachers. The most favoured constructivist components were personal relevance and student negotiation.

Anagun and Anilan (2013), using a Turkish translated version of the CLES, measured 449 primary school teachers' perceptions about their own learning environment. Teachers perceived personal relevance, uncertainty, and student negotiation positively.

Some studies compared teachers and students' perceptions. Vennix et al., (2017) found statistically significant differences for personal relevance between teachers (n = 13) and high-school students (n = 729) in both the US and the Netherlands who were involved in Science, Technology, Engineering and Mathematics (STEM) outreach activities. Teachers perceived personal relevance very positively and uncertainty positively. Students reported positive perceptions for personal relevance and uncertainty. Differences between students and teachers in their study were statistically significant, with students reporting less positive perceptions than teachers.

Abd Hamid (2006) investigated the extent to which teachers were able to develop constructivist behaviours after being involved in one year-long project. Twenty-seven teachers and 321 students participated voluntarily in the study. The study revealed significant growth by both teachers and students concerning constructivist perceptions over time and for the Personal Relevance, Uncertainty, and Student Negotiation subscales. Prior to training, teachers perceived personal relevance as very positive, uncertainty as neutral and student negotiation as slightly positive. There were statistically significant differences when comparing teachers and students' perceptions of uncertainty and student negotiation, but not for personal relevance.

Johnson and McClure (2004) found no statistically significant differences for personal relevance between students ($n = 464$) and teachers ($n = 290$) in their study of elementary, middle, and high school in-service and preservice US science teachers and Australian and US students. Teachers perceived personal relevance as positive.

In conclusion, the above-mentioned studies revealed a positive relationship between teachers' beliefs and their perceptions of a constructivist learning environment (Beck et al., 2000; Berliner, 2005; Savasci & Berlin, 2012; Saylan et al., 2016). In general, teachers also had positive perceptions of personal relevance, uncertainty, and student negotiation. In other words, teachers thought that they applied constructivist principles in their classroom to a considerable degree. In most studies, personal relevance was the most positively perceived component. Studies that have observed teachers' classrooms have reported limited presence of constructivist principles in teachers' classroom practice. In general, teachers seem to perceive their learning environment more positively than students with respect to the constructivist parameters (den Brok et al., 2006; Fraser, 2007; Wahyudi & Treagust, 2003; Wubbels et al., 2006). Statistically significant differences were found when teachers' and students' perceptions were compared. However, no published study could be found that explored teachers' views about the relevance of creating a learning environment aimed at innovation competence in higher education. Therefore, the current study aimed at mapping teachers' perceptions of the existing learning environment for innovation competence and investigating how personal beliefs about the relevance of innovation competence and creative self-efficacy relate to the creation of learning environments in higher education.

3.2.3 Research questions

Following the reviewed literature, this study was designed to answer the following research questions:

1. What are Built Environment teachers' perceptions regarding the focus on innovation competence at the curriculum level?
2. What are Built Environment teachers' perceptions of their own learning environments for innovation competence development?
3. To what extent do teachers' perceptions of their own learning environments differ from those of the students?

4. To what degree do Built Environment teachers believe:
   a. .... that it is relevant for teaching to aim to develop innovation competence?
   b. .... in their own creative self-efficacy?
5. What is the association between Built Environment teachers' beliefs and perceptions regarding the school's learning environments (research questions 1 and 4) and their perceptions of their own existing learning environment (research question 2)?

3.3 Method

3.3.1 Context and sample

A survey was administered by email via the various schools' heads of department to teachers at eight universities of applied sciences in the Netherlands where Built Environment programs were offered. Built Environment departments at universities of applied sciences are required to develop students' innovation competence. Therefore, innovation competence is an end goal for all students enrolled in Built Environment programs. Innovation competence is considered one of the core competences necessary for career success in the professions within the Built Environment discipline. Correspondingly, several educational steps have been taken towards realizing the above objective in the various Built Environment departments.

An online questionnaire with an explanatory cover letter was emailed to a random sample of 120 Built Environment teachers at the various schools. After an initial mailing, three follow-up reminder emails were sent. Overall, 94 teachers completed the questionnaire, and subsequent analyses were based on their responses. Participants were teachers from eight different universities of applied sciences in the Netherlands offering a Built Environment program. Of the 94, 23% were female. Teachers' age ranged from 23 to 67 years old (M = 46.12, SD = 10.20). Their teaching experience varied from 1 to 27 years (M = 9.70, SD = 6.92). In terms of educational level, 20% of the teachers had an applied university/higher vocational education diploma (HBO), 68% of the teachers had a university education degree (WO), 2% of the teachers had a doctoral degree (PhD) and 7% of the teachers specified other kinds of degrees they had (e.g., post-HBO+, post-HBO education).

For the purpose of answering research question 2, student data from a previous study were used, collected from 130 students at the same Built Environment programs (Ovbiagbonhia et al., 2019). Of the 130 students, 27% were female. Students' ages ranged from 17 to 37 years old (M = 21.5, SD = 2.49). For more details about the student data, see Chapter 2.

3.3.2 Instrumentation

The questionnaire mapped teachers' perceptions about the identified teacher-related beliefs and perceptions of the learning environment with respect to innovation competence fostering. The items used a 7-point response scale ranging from 1 (strongly disagree) to 7 (strongly agree), unless otherwise noted. For details, see appendix B.

F*ocus on Innovation Competence at School/Curriculum Level* - This scale consisted of four items, created to measure a school's explicit focus on teaching for innovation competence development at the school/curriculum level. Factor analysis revealed a one-factor solution, accounting for approximately 60% of the common factor variance, with all four items loading meaningfully on the factor. Reliability in terms of Cronbach's α was .76.

Perception of the Learning Environment - The Personal Relevance, Uncertainty, and Student Negotiation scales from the Constructivist Learning Environment Survey (CLES; Taylor et al., 1994) were used to assess the explicitness of and focus on innovation competence-supportive learning activities in the school environment. The scale measuring personal relevance in our study was comprised of four items, with a Cronbach's α of .65. The scale for uncertainty consisted of five items, with a Cronbach's α of .76. The scale for student negotiation consisted of just two items, with a Cronbach's α of .86. Factor analysis revealed satisfactory factor loading for all scales.

Beliefs: Relevance of Innovation competence instruction - Teachers were asked to respond to one item using a 7-point scale ranging from 1 (very irrelevant) to 7 (very relevant), asking if they considered innovation competence relevant. Teachers were also asked to indicate on a single binary item (yes or no) if they deliberately taught their students to become innovative in their major teaching area. Respondents who answered yes were asked to further specify the subject/course/module name and what year in the program of study the course was taken. This approach has also been followed by other researchers investigating creativity in the curriculum (Adams, 2013; Aish, 2014; Shaheen, 2011).

Beliefs: Teachers' Creative Self-efficacy - A three-item scale originally developed by Tierney and Farmer (2002) to measure creative self-efficacy formed the basis for measuring teachers' self-efficacy in the present study. The original three items were slightly reworded to fit our purpose and two new items measuring teachers' confidence in their ability to teach and assess their students' innovation competence were added, making a total of five items. The original items did not measure teachers' confidence to teach and assess students' innovation competence;

hence, we added those items. A factor analysis revealed a one-factor solution, accounting for approximately 60% of the common factor variance, with all items loading meaningfully on the factor. Cronbach's α was .84.

3.3.3 Data analysis

The questionnaire data collected from teachers were organized and then analysed statistically by calculating means and standard deviations (research questions 1 to 4) and computing correlations and conducting variance analysis (research question 5). To compare teacher and student perceptions of the learning environment, an independent samples t-test was conducted (research question 3). Effect sizes (partial η2 scores) were interpreted as follows (Cohen 1988): .01 was taken as a small effect size; .06 as a medium effect size; and .14 as a large effect size. Similarly, correlations were interpreted as follows (Cohen, 1988): $|r| = .10$ to .29 was taken as a weak association; $|r| = .30$ to .49 as medium; and $|r| = .50$ to 1.0 as strong.

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3.4 Results

Table 3.1 provides a description of the research questions, instruments/scales related to these research questions, sample items, average scale means and standard deviations. The results of the study will be reported per research question.

Table 3.1 Research questions, scale description, sample items, average scale means and standard deviations

Research Question	Instrument	Sample items	M	SD
RQ1	Focus on Innovation Competence (FIC)	At my school, innovation competence is an end goal.	4.10	1.28
RQ2	Personal Relevance (PR)	In my class, students learn about the world beyond the work field of Built Environment in order to become innovative.	5.03	.74
	Uncertainty (U) Student	In my class, students learn about the different innovative techniques people use in other areas.	4.85	.91
	Negotiation (SN)	In my class, students with other students discuss how to solve problems innovatively.	5.22	.89
RQ4a	Relevance of Innovation Competence (RICT)	[See section on instrument description.]	3.70	1.20
RQ4b	Creative Self-efficacy (CSE)	I am confident in my ability to teach my students how to become innovative.	5.09	.89

This item used a 7-point response scale where 7 = strongly agree and 1 = strongly disagree. N = 94.

3.4.1 Teachers' perceptions of focus on innovation competence at the curriculum level (research question 1)

For the questions concerning the focus on innovation competence development at the curriculum level, we sought to understand the extent to which teachers recognize innovation competence as an intended learning goal stated in the schools' curriculum and enacted in classroom learning goals and teaching practices. The results presented in Table 3.1 show, on average, neutral perceptions for focus on innovation competence. However, the standard deviation suggests relatively wide variation in scores.

3.4.2 Comparing teachers' and students' perceptions of the existing learning environment using CLES (research questions 2 and 3)

Table 3.2 Independent-samples t-test table

Scale	Teacher		Student				
	M	SD	M	SD	t	p	η^2
Personal Relevance (PR)	5.03	.74	3.83	1.36	-7.86	.001	.22
Uncertainty (U)	4.85	.91	4.02	1.44	-7.86	.000	.10
Student Negotiation (SN)	5.22	.89	4.15	1.59	-7.86	.001	.14

This item used a 7-point response scale where 7 = strongly agree and 1 = strongly disagree. Teachers: n = 94; Students: n = 130.

The results presented in Table 3.1 showed that, on average, teachers were positive about their focus on the three learning environment variables within the curriculum. An independent-samples t-test was conducted to compare the personal relevance, uncertainty and student negotiation scores for teachers and students (see Table 3.2). For personal relevance, there was a statistically significant difference in scores for teachers and students $t(221) = -7.86$, $p < .001$). The effect size was very large, showing that teachers were much more positive than students. For uncertainty, there was also a statistically significant difference in scores for teachers and students $t(221) = -7.86$, $p < .000$). The effect size was medium-large, again showing that teachers were more positive than students. For student negotiation, there was a statistically significant difference in scores for teachers and students $t(221) = -7.86$, $p < .001$). The effect size was large, again on average showing more positive perceptions for the teachers compared to the students.

3.4.3 Teachers' perceptions of the relevance of IC (research question 4a)

Regarding the question as to whether teaching students to become innovative is relevant, teachers reported, on average, that they found this somewhat relevant (see Tables 3.1 and 3.3).

Most of the teachers were 'sitting on the fence'; namely, 66% reported neutral relevance for teaching innovation competence in their area of teaching. Nearly one-fifth (19%) of the teachers considered developing students' innovation competence irrelevant. In this sample, 15% of the teachers considered developing students' innovation competence as somewhat relevant and none saw it as very relevant.

Table 3.3 Frequency table for responses concerning relevance of innovation competence instruction (RICT)

Scale	frequency	percentage
Very irrelevant	13	13.8
Irrelevant	0	0
Somewhat irrelevant	5	5.3
Neither relevant nor irrelevant	62	66.0
Somewhat relevant	12	12.8
Relevant	2	2.1
Very relevant	0	0
Total	94	100.0

This item used a 7-point response scale where 7 = very relevant and 1 = very irrelevant. N = 94.

Teachers were also asked to specifically indicate the course/module where they deliberately teach their students to become innovative. Of the 94 teachers who responded as to whether they explicitly focused on innovation competence instruction in their major area of teaching, 43 teachers (45.7%) indicated that they indeed focused deliberately on innovation competence, whereas 49 (52.1%) indicated no such teaching focus. Two teachers did not respond. Of the 43 teachers who indicated that they deliberately taught students to become innovative, 31 teachers specified a course or module dedicated to the development of students' innovation competence in their major teaching program. The courses or modules they specified could be classified under two headings: general or broad subject areas - a total of 29 general subject area courses were specified, which amounted to 94% of the total (e.g., all year 1, 2 and 3 courses; architecture; final year projects); just two specific courses were mentioned (e.g., "In courses related to research, I try to encourage students to follow their ambition/interest as a motivation. Also, I teach students how to use techniques to improve creative thinking.").

3.4.4 Beliefs teachers hold about their creative self-efficacy (research question 4b)

Teachers' beliefs about their ability to teach innovation competence were measured via the Creative Self-efficacy scale. The results presented in Table 3.1 show that on average teachers were positive about their creative self-efficacy. The standard deviation suggested little variation in scores.

3.4.5 Associations between teacher-related beliefs and context-related perceptions, and perception of the learning environment (research question 5)

We used a multiple regression analysis to investigate the relationships between scores on the three learning environment scales (personal relevance, uncertainty, student negotiation) and creative self-efficacy, school focus on innovation competence instruction and relevance of innovation competence instruction. First, we discuss the results of the correlation analysis presented in Table 3.4. As can be seen in Table 3.4, scores for personal relevance (PR) and uncertainty (U) were both positively and statistically significantly correlated with the teacher's ratings of the school's focus on innovation competence (FIC).

Table 3.4 Bivariate correlation matrix of the variables considered

Scale	Correlations					
	FIC	RICT	PR	U	SN	CSE
Focus on Innovation Competence (FIC)	1					
Relevance of Innovation Competence (RICT)	.13	1				
Personal Relevance (PR)	.22*	.04	1			
Uncertainty (U)	.23*	-.15	.55**	1		
Student Negotiation (SN)	.06	.06	.46**	.20	1	
Creative Self-efficacy (CSE)	-.09	-.01	.24*	.08	.23*	1

*N = 94 * $p < 0.05$; ** $p < 0.01$.*

In order to determine the joint and unique relationships between each of the learning environment scales, teacher-related beliefs and teachers' perceptions of focus on innovation competence at the curriculum level, four stepwise multiple regression analyses were conducted. The first regression analysis aimed to understand the joint and unique relationships of the various variables with the school's focus on innovation competence. The other three regression analyses investigated the joint and unique relationships of each of the constructivist learning environment constructs with the remaining variables.

The first regression analysis indicated that the five predictors (personal relevance, uncertainty, student negotiation, creative self-efficacy and relevance of innovation competence instruction) together explained 10.4% of the variance in scores for teachers' perceptions of the school's focus on innovation competence. However, only relevance of IC ($\beta = .15$, $p = .03$) significantly and positively predicted focus on innovation competence. Thus, the more they perceived there to be a focus on innovation competence at the curriculum level, the more teachers perceived innovation competence to be relevant. The results of the second regression analysis indicated that the three predictors (creative self-efficacy, focus on innovation competence at the curriculum level and relevance of innovation competence instruction) explained 11.5% of the variance in personal relevance scores. Creative self-efficacy ($\beta = .22$, $p = .010$) and focus on innovation competence at the curriculum level ($\beta = .14$, $p = .021$) were statistically significant predictors of personal relevance. Thus, the stronger the teachers' perception of focus on innovation competence at the curriculum level and their beliefs in their own creative self-efficacy, the more strongly they reported teaching for personal relevance for students in their major teaching area. The third regression analysis indicated that the predictors (creative self-efficacy, focus on innovation competence at the curriculum level and relevance of innovation competence instruction) explained 9.4% of the variance in uncertainty scores. Focus on innovation competence at the curriculum level ($\beta = .19$, $p = .012$) was a significant predictor of uncertainty. Thus, the more teachers perceived there to be a focus on innovation competence at the curriculum level, the more strongly they reported teaching about uncertainty for students in their major teaching area. The fourth and final regression analysis indicated that the predictors (creative self-efficacy, focus on innovation competence at the curriculum level and relevance of innovation competence instruction) explained 6.2% of the variance in student negotiation scores. Creative self-efficacy ($\beta = .26$, $p = .019$) significantly predicted student negotiation. Thus, the more strongly teachers believed in their own creative self-efficacy, the more they included student negotiation in their instruction within their program.

3.5 Discussion and conclusion

This study aimed at mapping teachers' perceptions of the existing learning environment aimed at innovation competence instruction, teachers' beliefs and the interplay between their beliefs and perceptions. The conclusions are summarized with regard to three areas, namely: beliefs about innovation competence relevance; perceptions of the learning environment aimed at innovation competence; and the relationship between beliefs about innovation competence relevance and perceptions of the learning environment.

Strikingly, teachers' beliefs about innovation competence relevance were, on average, negative to neutral. Only a few teachers considered teaching for innovation competence to be (somewhat) relevant, while some were even negative about its relevance. The majority of the teachers (62; 66%) had a more neutral opinion. Just 12 (13%) perceived teaching for innovation competence as somewhat relevant, while 13 teachers (14%) considered innovation competence instruction very irrelevant. The question is, why is this the case? One explanation is that innovation competence may be a relatively new topic and a complex competence to teach. Teachers may not have the know-how to integrate innovation competence in their teaching routine, as limited teaching guidelines exist for this competence. This could explain why studies that observed teachers' practice have rarely found traces of teaching aimed at innovation competence (Savasci & Berlin, 2012). Another explanation is related to the complexity of innovation competence: teachers may believe that students are not capable of learning to become innovative, as they see that students still struggle to reproduce the knowledge passed along to them by their teacher. Studies have shown that the beliefs that teachers have about students affect their teaching practice (Bassett, 2004; Beck et al., 2000; Davis & Rimm, 1998; Saylan et al., 2016; Sternberg & Williams, 1996). To teach innovation competence, teachers also need some professional guidance. Without professional guidance and hands-on practice, teachers may not possess the right conceptions about innovation competence, nor may they be able to teach or assess this competence with students. Studies where teachers received some professional support revealed that teachers valued innovation competence more and that such teaching was effective in raising students' innovation competence (Abd Hamid, 2006; R. E. West et al., 2012; Wright et al., 2013).

Teachers rated their own creative self-efficacy beliefs positively in the current study. This finding is consistent with past studies (Aish, 2014; Beghetto, 2010; Plucker et al., 2004), where teachers also displayed confidence in their creative abilities. Similar to previous studies, teachers in general reported a high level of creative self-efficacy with respect to the confidence they had in fostering students' innovation competence (Al-Nouh et al., 2014; Rubenstein et al., 2013). This is a good thing, because it displays teachers' confidence and beliefs about their own self-competence in terms of the required knowledge, skill and ability for developing students' innovation competence. The high level of teachers' creative self-efficacy also represents a large factor in teaching enactment (Beck et al., 2000; Davis & Rimm, 1998; den Brok et al., 2006; Saylan et al., 2016).

Teachers' neutral perception of the focus on innovation competence at the curriculum level is surprising given the relevance and role of innovation competence for the economy and society. This suggests that teachers in the Built Environment domain at universities of applied sciences perhaps think that innovation competence is too ambitious for their students. These teachers may still have the notion that their students should primarily be trained to resolve practical problems, not innovative problems, and that innovative problems are reserved for scientific university students. This is in line with past studies on how teachers' beliefs about students affect the learning environment (Bassett, 2004; Beck et al., 2000; Davis & Rimm, 1998; Saylan et al., 2016; Sternberg & Williams, 1996).

In the current study, teachers rated all three CLES variables positively, similar to the results found in the reviewed literature (Anagun & Anilan, 2013; Saylan et al., 2016; Vennix et al., 2017). However, teachers rated student negotiation the highest, contrary to what was seen in the literature, where personal relevance was often rated highest (Anagun & Anilan, 2013; Saylan et al., 2016; Vennix et al., 2017). This means that teachers in the Built Environment domain consider providing students the opportunity to communicate one with another to be relevant. Similarly, in the current study, students rated student negotiation highest, which complements teachers' views in this respect. Higher rating of student negotiation may mean that student negotiation suits higher education better, whereas personal relevance probably suits lower education better. Students also work more in groups in higher education than they do in lower education, making student negotiation more visible in the learning environment. Uncertainty was rated lowest by teachers, which is in line with Vennix et al. (2017).

Teachers and students disagreed about the level to which a perceived innovation supportive learning environment was present. We found statistically significant differences in perception between teachers and students. Teachers were clearly more positive about the presence of these aspects of an innovation-supportive learning environment than students could confirm. Such a difference was expected, as previous research that compared teacher and student perceptions found similar results (den Brok et al., 2006; Fraser, 2007; Wahyudi & Treagust, 2003; Wubbels et al., 2006). The difference in perceptions can be attributed to the fact that teachers have an active role, rather than an observer role, in the learning environment (den Brok et al., 2006; Fraser, 2007; Vennix et al., 2017; Wahyudi & Treagust, 2003; Wubbels et al., 2006). According to Chan and Yuen (2014) and Hondzel (2013), when teachers were asked if they support creativity in their practice, they often reported a high-level focus on the development of students' creativity. However, studies that have observed teachers' actual teaching behaviours in practice with respect to fostering creativity have often reported disappointing results (Alkhars, 2013; Lev-Zamir & Leikin, 2013; Meyer & Lederman, 2013; Shaheen, 2011). Teachers are the major actors in creating the learning environment. For this reason, they may be more inclined to report positive perceptions of their own learning environments. Another explanation could be wishful thinking on the part of the teacher. It may also be that the students in this domain are perhaps too critical, or fail to recognize innovation competence supportive elements in their learning environments. This result demonstrates the relevance of gathering both teachers and students' perceptions about the learning environment, as students' learning is usually based on what they experience themselves, not what teachers think they do. Gathering both perspectives enables them to complement each other.

3.6 Understanding the associations between innovation competence and learning environments

Correlational analysis also showed that creating an innovation competence supportive learning environment was related to the beliefs the teacher held about the relevance of innovation competence instruction, which is consistent with the conclusions of previous studies (Beck et al., 2000; Saylan et al., 2016). There was a statistically significant correlation, as expected, between each of the constructivist learning environment scales (personal relevance, uncertainty, student negotiation). Perceived personal relevance and perceived uncertainty in the learning environment were both correlated with focus on innovation competence. Multiple regression analyses showed that teachers' creative self-efficacy beliefs significantly predicted personal relevance. Similarly, school focus on innovation competence significantly predicted perceived uncertainty, while creative self-efficacy significantly predicted perceived student negotiation. Creative self-efficacy beliefs and focus on innovation competence at the curriculum level are important components for the creation of an innovation competence supportive learning environment.

This study added further to understandings about what dimensions of a constructivist learning environment are important for innovation competence development, revealing that personal relevance, uncertainty and student negotiation are helpful dimensions. It provided empirical data to validate theoretical discussions about the relationships between teachers' perceptions of constructivist learning environments aimed at innovation competence and their beliefs about innovation competence relevance and creative self-efficacy. Finally, the findings of this study can inform the Built Environment engineering educational domain, because developing students' innovation competence via creating a constructivist learning environment is emphasized in that domain.

3.7 Limitations

There were some limitations involved in the present study that should be addressed in future research. First, this study provided unique insights about the existing learning environments, particularly about the differences in perception between students and teacher regarding the focus on innovation competence in practice. Although these findings are in line with previous studies about teacher-related beliefs and context-related perceptions about innovation competence

(Aish, 2014; Andiliou & Murphy, 2010; Bereczki & Kárpáti, 2017; Shaheen, 2011), as well as with prior research on learning environments (den Brok et al., 2006; Fraser, 2007; Wahyudi & Treagust, 2003; Wubbels et al., 2006), our study says little about the actual situation regarding innovation competence instruction in practice, as no classroom observations were conducted. To understand the actual situation regarding innovation competence instruction in practice, research including classroom observations and interviews with teachers on why and how they go about innovation competence instruction in practice would be helpful. Second, further quantitative and qualitative research needs to be conducted with teachers about aspects such as the role of the physical environment, with lesson observations and in-depth interviews with various stakeholders not covered in this study, in order to validate some of the findings of the present study, such as those concerning relevance and focus on innovation competence. Finally, our study did not document how teachers intended to develop students' innovation competence nor did it map relevant pedagogical principles for fostering innovation competence. The findings of this current study do present a first glimpse at how important teachers regard innovation competence to be in their teaching and curriculum, and to what degree they think they realize a constructivist learning environment conducive to innovation competence. To create innovation competence- supportive learning environments, sound design principles are needed. Therefore, future studies are needed to develop, implement and test sound design principles for developing students' innovation competence in practice.

3.8 Recommendations

Based on the findings and conclusions of the present study, the following recommendations for educational practice and policy can be made for supporting teachers in creating an innovation competence-supportive learning environment in their classroom practice. First, there is sufficient evidence in the literature that although teachers proclaim themselves to value innovation competence, they do not really *deliberately* focus on developing students' innovation competence in their classroom practice (Andiliou & Murphy, 2010; Bereczki & Kárpáti, 2017). Teachers and students disagreed about the level to which a constructivist learning environment aimed at innovation competence was present, in line with past studies (den Brok et al., 2006; Fraser, 2007; Wahyudi & Treagust, 2003; Wubbels et al., 2006). Therefore, teachers and school leaders need to reflect on the relevance of developing innovation competence in classroom practice and how to make it visible for students, they need to discuss how to foster innovation competence at what levels of study and they need to develop their own creativity and proficiency in fostering students' innovation competence (Aish, 2014; Andiliou & Murphy, 2010; Fives & Buehl, 2012). Teachers in a particular teaching domain must come together to discuss and reflect on the meaning of innovation in their specific domain, relate their beliefs, practices and understanding to the established theories about innovation, analyse novel teaching examples in other domains through classroom observations, and have discussions with experts about how to create effective instruction and tasks (Andiliou & Murphy, 2010; Morais & Azevedo, 2011). Comparing and discussing their own perceptions in comparison with, for example, those of their students and figuring out potential factors explaining differences may also be relevant in this respect.

Second, teachers are the main vehicle for realizing any learning goal for students (Beghetto, 2010). The results from the current study showed that only a minority of the teachers considered teaching for innovation competence to be relevant. To cultivate innovation competence, teachers need to develop positive attitudes and beliefs towards innovation competence and develop innovative teaching behaviour. Therefore, school leaders need to work closely with teachers and be more supportive by providing the necessary professional guidance needed for the realization of teaching that develops innovation competence. Teachers also need to understand that focusing their teaching on innovation competence not only helps students learn how to become innovative, but also serves as a way of learning: "In this view, student imagination and curiosity drive the learning process, and creativity becomes the vehicle for understanding" (Beghetto & Plucker, 2006, p.324).

Third, in the present study, the focus on innovation competence and relevance of innovation competence instruction were perceived to be relatively low. Developing students' innovation competence requires creating an innovation competence-supportive learning environment. Therefore, teachers need to embrace and integrate constructivist learning environment principles when creating learning environments aimed at innovation competence. This involves: making teaching and learning personally relevant to students (i.e., engaging students in authentic tasks in which they develop solutions for real-world problems within and outside Built Environment domains); providing students with the opportunity to experience scientific knowledge as arising from theory-dependent inquiry involving human experience and values, and as evolving, non-foundational, and culturally and socially determined (i.e., engaging students in tasks in which past innovations within and outside Built Environment domains are analysed); and encouraging collaboration and communication among students (i.e., encouraging students to discuss how to solve problems innovatively in terms of what method to follow and approaching problem and solutions methodically).

Finally, studies that have observed teachers' practice have found few traces of teaching aimed at innovation competence (Savasci & Berlin, 2012). In the present study, teachers and students disagreed about the presence of innovation competence-supportive learning environments. Past studies have shown that professional guidance and hands-on activities assist teachers in the creation of innovation competence-supportive learning environments in various domains. Studies where teachers received some professional support revealed that teachers valued innovation competence more and that such teaching was effective in improving students' innovation competence (Abd Hamid, 2006; R. E. West et al., 2012; Wright et al., 2013). Therefore, creating a teaching intervention specifically for innovation competence and implementing it in Built Environment practice could assist in redirecting teachers' focus to innovation competence. Explicitly teaching for innovation competence in Built Environment practice will also help students experience innovation competence development in their learning environment, as innovation competence instruction is made explicit and assessed.

4

Six design principles for fostering students' innovation competence in engineering education

The implicit focus on innovation competence instruction by teachers revealed via the context and needs analysis suggested that innovation competence-supportive learning environments were somewhat limited in Built Environment engineering educational domains. Therefore, chapter 4 investigates design principles that could facilitate innovation competence-supportive learning. Based on six design principles drawn from the constructive alignment concept, constructivist learning principles, and the 4C/ID model, an instructional prototype for innovation competence-supportive learning was created.

Abstract

Developing students' innovation competence is relatively new to higher applied university education. As a result, teachers and other educational institutions are struggling with how to foster this competence in students. This chapter presents and discusses six design principles that can assist teachers in developing teaching that supports innovation competence. Together these principles represent the key issues related to instructional teaching programs for innovation competence education. The resulting patterns are potentially beneficial for both researchers and practitioners. Translation of these principles into Built Environment engineering education are discussed.

4.1 Introduction

Engineering students are expected to be equipped with the competence to solve real-world ambiguous problems innovatively (Beghetto, 2010; Liebenberg & Mathews, 2010; Sawyer, 2014). Unfortunately, research reports have shown that in general, teachers do little to foster innovation competence in students or do so in an implicit way (Beghetto & Kaufman, 2013; Ovbiagbonhia et al., 2019; Passig & Cohen, 2014; Root-Bernstein & Root-Bernstein, 2017). Ovbiagbonhia et al. (2020) studied whether teachers in the domain of Built Environment engineering education considered teaching innovation competence to be relevant. The researchers found that only 15% of the teachers considered teaching for innovation competence relevant, while the majority had a more neutral or even negative opinion. Their study also showed a lack of a systemic teaching focus on innovation competence, suggesting an urgent need for design principles that could help teachers redirect their attention to the teaching of innovation competence.

The literature on higher education reveals an increased interest in investigating innovation competence (Fisher et al., 2011; Keinänen & Kairisto-Mertanen, 2019; Liebenberg & Mathews, 2010; Penttilä, 2016; C. Richardson & Mishra, 2018; Trilling & Fadel, 2009). Some studies have looked at an aspect of innovation competence instruction such as how to improve ideation techniques in solving problems (Kramer et al., 2015; Lumsdaine et al., 1999; Messmann & Mulder, 2011; Sternberg, 2012; R. E. West et al., 2012). Others have attempted to address innovation competence assessments in the domain of Engineering education (Nielsen, 2015; Passig & Cohen, 2014; Penttilä & Kairisto-Mertanen, 2012; Wright et al., 2013). Yet, not much insight can be drawn from these studies for the development of instructional design principles for innovation competence. To adequately foster innovation competence development through instruction, principles that describe how to design the teaching and learning activities are a prerequisite (Biggs & Tang, 2011; Posner & Rudnitsky, 2006; Van Merriënboer et al., 2007).

There is no one right way or principle for approaching innovation competence instruction or assessment. The literature suggests that active student involvement instead of didactic teaching practices is critical to promote and facilitate innovation competence (Beghetto & Plucker, 2006; Dezutter, 2011; Fisher et al., 2011; Keinänen & Kairisto-Mertanen, 2019; C. Richardson & Mishra, 2018; Sawyer, 2014). Innovation competence is recognized in many educational domains as a key educational learning goal and essential 21st century skill that should be supported in students (Chan & Yuen, 2014; K. Robinson, 2011; Wagner, 2010). Therefore, a teaching approach intended to foster students' innovation competence must be focused on realizing clear, measurable, but holistic learning outcomes (Amabile, 1996; Biggs & Tang, 2011;

Wright et al., 2013). Teaching strategies such as problem-based learning, writing reflective journals, and debates are reported to help (Fisher et al., 2011; Sternberg, 2012; R. E. West et al., 2012), because these strategies help engage students in their learning process and can foster their innovation mindset (e.g., creativity, leadership, energy, creative self-efficacy, risk propensity and skill at solving ambiguous problems; (Chell & Athayde, 2009; Fisher et al., 2011; Hurt et al., 1977; Tierney & Farmer, 2002). Fisher et al. (2011) posited that although there are many strategies that can impact students' innovation competence, teaching sound creative principles is regarded as most effective and can greatly improve students' innovation competence. Past research has revealed the effectiveness of teaching sound creative principles to students and that students' ability to develop their creative potential improved after receiving creativity instruction (Kramer et al., 2015; Lumsdaine et al., 1999; Sternberg, 2012; R. E. West et al., 2012). Several descriptive studies across domains have suggested that many teachers have a misconception of creativity and that they lack a theoretical foundation for teaching creativity techniques to their students, which can be detrimental to creating an innovation competence-supportive learning environments (Beghetto & Plucker, 2006; Dalke et al., 2007; C. Richardson & Mishra, 2018). However, there is some evidence in the literature that providing specific hands-on activities pertinent to innovation competence to students enhances the students' innovation competence (Beghetto & Plucker, 2006; Dalke et al., 2007). According to C. Richardson and Mishra (2018), current education primarily focuses on engaging students in teacher-led activities and uniform tasks, which is highly constraining to creativity (Beghetto, 2010; Plucker et al., 2004). Unfortunately, principles that describe how to design teaching and learning methods that foster innovation competence are not readily available. The goal of this study is, therefore, to fill the gap in the literature by discussing six design principles for the teaching of innovation competence. Six design principles will be described, followed by the description of the translation of the six principles to an instructional prototype designed for the Built Environment domain of study.

In the following section, we discuss the rationale behind the six design principles, shown in Table 4.1, followed by a section presenting in greater detail their underpinnings and their instructional translation. At the end, conditions for successful implementation and an instructional prototype for innovation competence instruction will be presented, based on these principles.

The section presenting the design principles in greater detail will discuss two elements each time: the underpinning and the translation of each design principle. The underpinning presents the description of the theoretical background of, support for, or origin of the design principle. The *translation* pertains to the specific application of the design principles in student and teacher activities and assessment rubrics, which are extensively described in appendices C and D and G, H, and I, respectively. The sequencing of the design principles does not necessarily represent the order in which they are applied, as each design principle can be used independently.

4.2 Rationale behind the principles

The rationale behind the six design principles as depicted in Table 4.1 is derived from insights drawn from different sources, namely, the curriculum instruction model for complex competencies - the 4C/ID model (Van Merriënboer & Kirschner, 2007), constructive alignment (Biggs & Tang, 2011), the simplified innovation process (Amabile, 1996; Ovbiagbonhia et al., 2019; Wright et al., 2013), and constructivism (Beghetto & Plucker, 2006; Dezutter, 2011; Sawyer, 2014). These theories are interconnected and build upon each other. As such, each design principle can be linked to one or more of the theories. In a nutshell, the constructive alignment rationale formed the overarching basis upon which the six design principles were organized into learning goals/ outcomes (A), activities (B, C, D) and assessments (E, F). According to constructive alignment, these three elements should be aligned with each other, such that goals are assessed, teaching activities contribute to realizing the goals, and assessments measure the extent to which the goal are attained (Biggs & Tang, 2011).

4

Table 4.1 Design principles for the teaching and development of innovation competence

Domain	Design principle
Goal: Teaching & learning goal	Define holistic but measurable learning goals.
Explicit Teaching: Teaching & learning sequence	Incorporate constructivist learning principles in the learning environment. Base teaching on the innovation process sequence. Teach sound creative techniques.
Assessments: Students' learning outcomes	Ensure that assessments of students' learning outcomes are simple to use, systematically aligned with the learning activities, and concise but comprehensive enough to capture relevant aspects of innovation competence. Focus assessments of students' learning outcomes more on process than product.

4.3 Goal: learning outcomes and teaching goals

It is often advised to spell out the intended learning outcomes or goals before proceeding to the design of any instructional practice (Biggs & Tang, 2011). Outcomes or goals are clear statements of expected behaviours that students are to demonstrate as a result of the instruction. Therefore, instructional goals must be created before the design or implementation of any instructional intervention (see also design principle A). The learning goals were in this case derived from the simplified innovation process (see the section on design principle C for details), which comes from the work of Amabile (1996) and Wright et al. (2013). The intended learning outcomes are the vehicle for gaining understanding about innovation competence, upon which teaching, learning and assessments are based (design principles B, D, E, and F). In this sense, the intended learning outcomes form the backbone of the instructional design. These learning goals can be found in Table 2. Attainment of a learning outcome requires proficiency and engagement in all aspects of the components of innovation competence. For instance, to identify an innovative problem or question, the students must employ knowledge, skills, and attitudes such as creativity, leadership, energy, creative self-efficacy, risk propensity and solving of ambiguous problems (Amabile, 1996; Bialik & Fadel, 2015; Bikfalvi et al., 2010; Bjornali & Støren, 2012; Castillo et al., 2011; Cobo, 2012; Davies et al., 2013; Ovbiagbonhia et al., 2019; Wright et al., 2013).

4.4 Explicit teaching activities: teaching and learning sequence

To improve students' innovation competence, the teacher's role, behaviour, and beliefs about innovation competence are relevant aspects to consider in designing a learning environment that supports the development of innovation competence. However, if the teacher lacks essential knowledge and understanding of the innovation process, the resulting learning environment may not be supportive. The four-component instructional design (4C/ID) model for training complex skills provides useful guidelines for designing teaching practice and presentation of information for development of complex competence, such as innovation competence (Van Merriënboer & Kirschner, 2007). According to the 4C/ID model, the design of teaching practice can be based on two principles. First, information pertaining to the procedures and rules that describe how recurrent aspects of the skills needed to innovate and the prerequisite knowledge for performing the procedures or following the rules should be provided to students. Second, a description of the systematic approaches to problem-solving and heuristics that assist the students in performing either the whole cognitive skill or its non-recurrent aspects should be provided to students. These insights resulted in the creation of design principles A, C, D, E and F.

4.5 Assessment

Assessment is an essential component of teaching and learning, as it allows the quality of both teaching and learning to be measured and enhanced. According to Biggs and Tang's constructive model of alignment (2011), learning outcomes should be in line with the aims and implementation of the instruction. The learning outcomes express knowledge, skills and attitudes that integrate the content and activities and can be observed upon completing the module as a behaviour, skill, or discrete useable knowledge. Therefore, the assessment of students' innovation competence must be behaviour-based and conducted by teacher(s) who can observe students' performance in appropriate settings. This is often a challenge for teachers, who lack the time and resources needed for observations (one teacher to 14-25 or more students) and are traditionally more experienced in written exams as means of assessment. Therefore, keeping the assessment simple, clear and easy to use is a matter of necessity (design principle E). Focusing the assessment system on capturing the process students followed in arriving at an outcome should also not be overlooked (design principle F).

In order to describe the complex skills within innovation competence, a simplified innovation process was used (see Figure 4.1). The simplified innovation process in turn informed the construction of the learning goals (see Table 4.2), and the teaching and learning activities and assessment of the teaching and learning activities (see Appendix I). Following the 4C/ID model, each phase of the innovation process was supported and represented by relevant tasks and instructions per phase. Last, in order to provide adequate support to students for each phase of the innovation process, constructivist learning principles were adopted, such as real-world tasks and content, group work and an active student role (Amabile et al., 1996; Plucker et al., 2015; C. Richardson & Mishra, 2018).

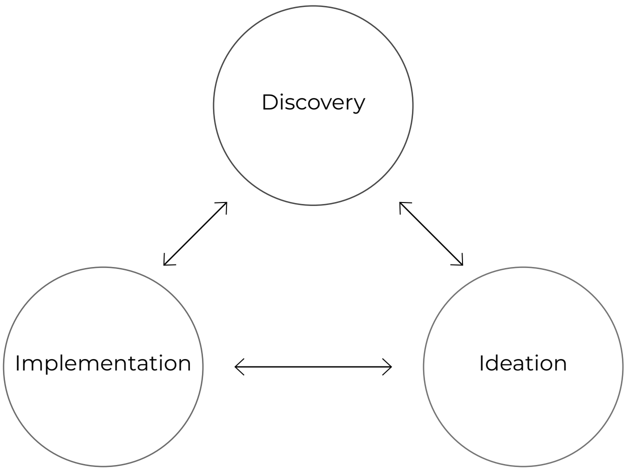

Figure 4.1 Innovation process phases

Constructivist principles have been used in prior studies as well, to create learning environments for students that support the development of innovation competence (Beghetto & Kaufman, 2014; Frazer, 2012; Lim & Sato, 2006). These principles emphasize understanding and focus on the process of knowing (Beghetto & Plucker, 2006; Dezutter, 2011; Sawyer, 2011). Constructivist principles assume that all new knowledge is constructed from the previous knowledge of the learner (Beghetto & Plucker, 2006; Dezutter, 2011). Therefore, constructivist-based teaching creates situations that challenge students' prior conceptions (Dezutter, 2011; Fraser, 2012), provide opportunities for collaborative work in which students will stimulate each other's learning (Fraser, 2012), and stimulate students to take charge or control of their own learning and develop metacognitive skills (Beghetto & Plucker, 2006; Fraser, 2012). According to constructivist theory, students learn actively, and construct their own meaning and their own knowledge (Fraser, 2012; Newton, 2013). Constructivism emphasizes the importance of making learning personally relevant for the learner through connecting the teaching activities within school to out-of-school experiences by engaging students in authentic tasks (Fraser, 2012; Lim & Sato, 2006). In a constructivist environment, learning is scaffolded. Examples of scaffolding include modelling a skill, providing hints or cues, and adapting materials or learning activity (Copple & Bredekamp, 2009).

4.6 Underpinnings and instructional translation of the principles

4.6.1 Design principle A: Define holistic but measurable learning goals

Underpinnings - Innovation competence must be seen as a way of learning involving a mind-set geared towards effective problem identification or questioning and problem solving (Root-Bernstein & Root-Bernstein, 2017). It involves asking the right questions in order to define the right problem (Dyer et al., 2009). Therefore, an important learning goal for innovation competence instruction is to define novel and appropriate problems systematically through exploration, questioning, analysis and evaluation of the problem context (Cross, 2002; Dyer et al., 2009; Dym, 1994; Lumsdaine et al., 1999; Root-Bernstein & Root-Bernstein, 2017).

Creativity is a vital component of the innovation process (Amabile, 1996; Kramer et al., 2015; Lumsdaine et al., 1999; Wright et al., 2013). It involves the systematic use of scenario-based, divergent, and convergent thinking to widen and generate as many creative ideas as possible (Amabile, 1996; Wright et al., 2013). Correspondingly, mastering the cognitive processes involved in generating creative ideas is an essential learning goal for the teaching of innovation competence.

For any solution to be labelled as an innovation, it must have demonstrated the applicability or usability of a developed solution for the identified problem (Root-Bernstein & Root-Bernstein, 2017). The implementation process involves constructing a prototype, testing, improving, and making preparations for diffusion (Rogers, 2003; Wright et al., 2013). Usually, new rounds of creative problem-solving skills (Lumsdaine & Binks, 2006) and reflective practices (Cross, 2002) are required during this phase. Therefore, a logical learning goal reflects the teaching and learning of the implementation process. Table 4.2 provides details about the intended learning outcomes/goals.

Translation - The principle, *define holistic but measurable learning goals*, was translated into students' learning tasks, teaching activities and assessment rubrics. Translation was realized by providing procedural descriptions of students' tasks concerning how to arrive at the acceptable products per activity within the innovation process, such as observation, exploration, and so forth. Just-in-time lectures were provided aimed at explaining the various strategies involved in finding or identifying an innovative question/problem, developing creative solutions and demonstrating the applicability of developed idea or solution. Students' learning was captured and assessed by reviewing their learning products and reflections using both formative and summative assessment methods. Coaching and feedback were provided at various intervals during the learning process. For further details, see the sections addressing description of the instructional prototype.

Table 4.2 Intended learning outcomes (ILO) for innovation competence

Intended learning outcomes	Definitions	Indicators
ILO 1. The student can systematically *discover* the problem gap in each problem context.	The ability to identify an original problem through deep questioning, analysis and synthesis	Find, frame/reframe old problem or question in an authentic way through analysis and problem-context exploration Identify the connected constraints or challenges within the problem Articulate the needs, goal and criteria or conditions for an effective solution
ILO 2. The student can *create* an original and appropriate solution to the articulated problem/question, following an established creative procedure/ process.	The ability to intentionally and systematically generate original and appropriate ideas using sound ideation techniques for idea generation, evaluation and solution judgement	Use sound ideation techniques that follow a distinct process whereby the method, system and principles are explicit and replicable
ILO 3. The student can *design and implement* an experimental plan intended to demonstrate the effectiveness or shortcomings of the generated solution(s) to problems.	The propensity to plan an experiment, demonstrate solution effectiveness or ineffectiveness, iterate, and reflect upon the actions undertaken	Develop sound experimental plan that is simple and executable Draw credible connections, associations and conclusions

4.6.2 Design principle B: Incorporate constructivist learning principles in the learning environment

Underpinnings - It has been established that constructivist learning principles foster the development of students' problem solving and conceptual development of higher order competences such as innovation competence (Kwan & Wong, 2014). To foster innovation competence in students, relevance can be promoted through connecting teaching with students' everyday experiences in forms of user-centred design learning and engaging in authentic activities, using open-ended tasks and real-world problems (Lim & Sato, 2006). It is important that students have the opportunity to engage with real-world problems in the field of study in order to have a rich and meaningful learning experience (Fasko, 2001, p.322). Uncertainty, according to constructivist principles, involves teaching students how to explore, collect, analyse, and use data to spark innovation (Dyer et al., 2009; Honebein, 1996). Uncertainty as used here refers to providing students with the opportunity to experience science as evolving, and culturally and socially determined. Students are made to understand that the process of knowledge creation occurs not only in individual contexts, but also through the interactions involved in social negotiations, collaborations, and experiences (Dyer et al., 2009). The literature provides strong evidence that students' innovation competence is enhanced when they are provided opportunities to work collaboratively with each other (Burgess & Addison, 2007; Dillon et al., 2007; Halsey et al., 2006; Rutland & Barlex, 2008; Wood & Ashfield, 2008). Group work or working in teams has been demonstrated to be a relevant feature of learning environments that support the development of innovation competence (Burgess & Addison, 2007; Rutland & Barlex, 2008). Student negotiation involves providing students with the opportunity to share control with their teachers over the design and management of learning activities, assessment criteria, and social norms of the classroom. By negotiating the instructional goal and objectives with the students, the teacher acknowledges the relevance of students' involvement in learning. Teachers can use students' reflections to design learning activities for innovation competence development and create environments that encourage metacognition, self-analysis, regulation, reflection and self-awareness (Ernest, 1995). In such environments, the teacher is seen by the students as a co-learner, co-researcher and explorer as they engage in the tasks, and the teacher is resourceful and supportive of students' learning needs (Burgess & Addison, 2007; Rutland & Barlex, 2008). In this way, a safe and collaborative atmosphere is created where different students' learning approaches are valued.

Translation - Design principle B, *incorporate constructivist learning principles in the learning environment*, was translated through the use of personally relevant authentic real-world tasks, both individual and collaborative/group work, discussions and brainstorming sessions. The tasks were personally relevant to the students in that they connected to students' interests. Students were asked to first think individually about a given task and construct their own solution or idea and thereafter to bring their solution or idea to their group, which would critique and collectively construct the solution or idea. That way, they also learned that different viewpoints and uncertainty are part of the process. Group discussions were encouraged, and various mini trainings on how to conduct observations, articulate challenging questions, collect and analyse data from observation were organized. See Appendix C and D for more details.

4.6.3 Design principle C: Base teaching on the innovation process

Underpinnings – Teaching sequences for the teaching of innovation competence should be aligned with the simplified innovation process (Wright et al., 2013). Innovation competence, being a complex competence, can be attained if its teaching follows a systematic innovation process (Van Merriënboer et al., 2003; Wright et al., 2013). Amabile (1996) and others have identified stages or processes experts follow to arrive at an innovation. Analysis of these processes revealed three innovation domains or phases upon which teaching can be based. Therefore, the simplified innovation process entails three interrelated phases: opportunity or problem discovery, creativity or ideation, and testing or solution implementation; see Figure 4.1 for details. Correspondingly, the innovation process is directly linked with the intended learning outcomes upon which teaching, learning and assessment are based (see Table 4.2).

First, sensitivity to opportunity or problem discovery involves the teaching and learning of how to identify, structure and evaluate the opportunity within the context of a problem through creative exploration, creative questioning, research, and reflection (Amabile et al., 1996; Basadur et al., 1982; Cross, 2002; Dym, 1994; Lumsdaine et al., 1999; Martindale, 1999). According to Martindale (1999), sensitivity to opportunity discovery is one of the most essential characteristics of creative and innovative people in any field of human endeavour. The ability to raise questions that challenge the status quo is a crucial factor in problem finding (Root-Bernstein & Root-Bernstein, 2017). Developing this ability involves teaching the student how to use observation and exploration techniques to discover opportunities and raise challenging questions. According to Root-Bernstein and Root-Bernstein (2017), novel opportunities can be developed through the recombination of existing information, problem, and solution. Concretely, in this phase, the problem is defined through the process of ideation and evaluation of the created problem (Basadur et al., 1982). The performance/user requirements of the desired solution, and the goal and needs are also carefully formulated (Cross, 2002; Martindale, 1999). According to Root-Bernstein (2003), good solutions can be generated only when the problems are well-defined. Therefore, a critical step in teaching that is intentionally directed towards developing students' innovation competence must be to first consider teaching students how to articulate the right question and use the appropriate mechanisms to define the problem (Root-Bernstein & Root-Bernstein, 2017).

Second, ideation or creativity involves using different techniques to generate, evaluate and judge solutions for the defined problem (Lewis & Zuga, 2007; Voland, 2004). The creative phase requires both divergent and convergent thinking skills (Amabile, 1996; Dyer et al., 2009). During the divergent stage, as many solutions as possible are generated by thinking in scenarios or thinking outside of the box (Cross, 2002; Koen, 1985). The convergent stage is a solution reduction process where the defined performance/user criteria are used to select the best possible implementable solution to the problem (Dyer et al., 2009; Lumsdaine et al., 1999). Research has shown that teaching creative techniques can promote students' innovative capabilities. (Belski, 2009; Dym, 1994; Lumsdaine et al., 1999; West et al., 2012). Another proven strategy for promoting creativity is the use of group dynamics. The effectiveness of group dynamics in the generation of creative ideas has been stressed by various researchers (Amabile et al., 1996; Leung & Chiu, 2008; Paulus & Nijstad, 2003). The process of developing creative ideas is more of a group endeavour brought about by the interactions among individuals within the group or cultural setting than an individual effort (DeHaan, 2009; Kurtzberg & Amabile, 2000-2001; Sternberg & Lubart, 1999).

Third, solution implementation is entirely a test phase and iterative by nature, in which the emerging solution is validated, refined, restructured, and presented. Usually, this phase requires a new round of creative problem-solving skills (Amabile et al., 1996; Belski, 2009; Lumsdaine & Binks, 2006) and reflective practices (Cross, 2002). In this phase, prototypes, models, calculations, or simulations are developed as an object of study and mode of idea generation and solution evaluation. According to Dyer et al. (2009), all innovators engage in some form of experimentation, whether for the purpose of intellectual exploration or engagement in new surroundings. Innovative professionals try out new ideas by creating prototypes, simulations, models, and doing pilot studies (Dyer et. al., 2009). This implies that experimentation requires a well-designed plan for evaluation and user criteria – a statement of the criteria or conditions for a good solution in order to achieve the experiment's objectives. A clear and measurable goal for the experiment must also be formulated and conclusions should be drawn with respect to the experiment's purpose (Root-Bernstein & Root-Bernstein, 2017). Experimentation is thus a core activity on the road to innovation. Innovators experiment in order to understand how things work, to create new ways of doing things and to look for new experiences. Therefore, to foster experimentation by students for the purpose of learning to innovate, students should be informed by their instructors about the relevance of testing and evaluating their ideas through simulations, prototyping, or systematic modelling. Through experimentation, students can discover new ideas, problems or solutions that warrant new iterations of the innovation process.

Translation – Design principle C, *base teaching on simplified innovation process*, was translated into learning tasks that required students to individually and collectively identify innovative problems and develop solutions for the problems following a systematized process of innovation. An online platform was created for gathering students' findings per phase. Students were asked to give short pitches about their findings per phase. For instance, during the problem exploration phase, each group of six students was instructed to individually formulate a problem and collectively reformulate the problem using the group's input. The groups developed at least six innovative solution ideas for their collective problem (two radical and four incremental). They were then asked to make necessary combinations of the developed solution ideas and restructure the ideas using the initially developed *user criteria (conditions for an acceptable or good solution)* and to select the best solution or solution combination for the problem based on an analytical assessment model. This helped students learn to identify risks associated with their ideas, record possible returns, define decision points, identify possible uncertainties that were important, record the data required for the course of the assignment, and so forth. For details on the task descriptions, see Appendix C, D, E and F for each innovation phase.

4.6.4 Design principle D: Teach sound creative techniques

Underpinnings - Teaching creative techniques to help students to know how to develop original and appropriate solutions to problems is another key learning area in innovation competence education (Dyer et al., 2009; Root-Bernstein & Root-Bernstein, 2017). Innovative professionals are creative individuals who possess the ability to intentionally and systematically generate multiple solutions to problems using sound principles that follow explicit creative processes (Root-Bernstein & Root-Bernstein, 2017). According to Antonietti et al. (2011), creativity is an integrated process of widening, connecting, and restructuring. Widening involves keeping an open mind, being aware of the great number of elements that can be identified in a given situation, recognizing possible meanings that are not obvious, discovering hidden aspects and overcoming apparent constraints. Connecting represents the competence to establish reciprocal relationships among different elements, such as by thinking in scenarios, drawing analogies between remote things, combining ideas in odd ways and synthesizing a multiplicity of disparate elements into an overall structure. Restructuring involves looking at problems or solutions from multiple perspectives, which can include seeing things differently by inverting relationships between their elements, asking original questions and imagining what would happen if unusual conditions occurred.

According to Kramer et al. (2015), scenario-based thinking can be applied in the innovation process and has been confirmed to be effective for avoiding fixation (Jansson & Smith, 1991) at any stage of the innovation process (Daly & Seifert, 2019; Kramer et al., 2015; Root-Bernstein & Root-Bernstein, 2017).

Translation - Design principle D, teach sound creative techniques, was translated into lectures, workshops and coaching sessions in which students were assigned to work in small groups on various tasks relating to ideation using creative techniques. The lecture was centred around how to use scenario-based thinking identify new problems and generate as many ideas as possible about solutions for the articulated problem. In this way, students learned to avoid fixating on a single idea and the generation of known or common solutions would be limited. Table 4.3 provides details of some of the creative techniques that could be used by the students during the individual/group creative sessions. During coaching sessions, students were encouraged to organize meetings with experts to discuss their ideas and explore other aspects related to their generated problem or solution and to analyse past innovations. Students were required to record their learning experiences systematically in an individual and group logbook.

Table 4.3 Examples of some creativity training types and their application in the innovation phases

Type	Description	Suitable for
Creative problem-solving (CPS)	The Osborn-Parnes CPS process (Osborn, 1963) structures problems into five stages: fact finding, problem finding, idea finding, solution finding and acceptance finding. The CPS creative technique provides strategies for developing as many ideas as possible and their evaluation.	Suitable for ideation phase
Brainstorming	Brainstorming was developed by Alex Osborn (1963) as a creative technique used for developing as many ideas as possible.	Suitable for ideation phase
Lateral and vertical thinking	According to Edward de Bono (1970), there are just two forms of thinking: vertical thinking, which involves the implementation and utilization of already existing ideas or innovations ('digging same hole deeper"), and lateral thinking, which involves new ideas ("digging a hole somewhere else"). According to this concept, 'escape' and 'provocation' are the two main processes necessary to stimulate lateral thinking. Escape consists of rejecting assumptions and pre-formed concepts by shifting perspectives. Provocation, on the other hand, consists mainly of suspending judgement.	Suitable for problem discovery, ideation, and implementation phases

4.6.5 Design principle E: Ensure that assessments of students' learning outcomes are simple to use, systematically aligned with the learning activities, and concise but comprehensive enough to capture relevant aspects of innovation competence

Underpinnings – It has been argued that innovation competence instruction should be aligned with the innovation process (Amabile, 1996; Wright et al., 2013). Therefore, the assessment of students' innovation competence should capture the learning process followed in each phase of the innovation process. It has been argued that students' learning is captured by following formative assessment principles (Black et al., 2003; Sadler, 1998). Through formative assessment, what is to be learned is made clear to students and teachers (Beghetto, 2005; Simplicio, 2000). Formative assessments also allow teachers to make informal judgements and to evaluate students' innovative work in several ways, including collecting students' work in portfolios, peer-assessments and self-assessment. Most importantly, this assessment is not intended to judge the students, but to assist students to learn and to understand the innovation process better (Beghetto, 2005; Black et al., 2003; Sadler, 1998; Simplicio, 2000). Therefore, the assessment of students' innovation competence learning must be simple to use, systematically aligned with the learning activities, and concise but comprehensive enough to capture relevant aspects of the trained competencies (Biggs & Tang, 2011; Marin-Garcia et al., 2016; Posner & Rudnitsky, 2006; Van Merriënboer et al., 2007).

Translation – Design principle E, *ensure that assessments of students' learning outcomes are simple to use, systematically aligned with the learning activities, and concise but comprehensive enough to capture relevant aspects of innovation competence,* was translated into an assessment rubric (Appendix G) and was used to gather data about students' learning in both formative and summative ways. The various learning products and process for each intended learning outcome were highlighted and graded in the rubric. For instance, the assessment rubric focused on the quality of problem construction in terms of how the student developed their problem statements, found facts, designed the user criteria, created ideas, resolved learning issues, and worked methodically and systematically towards problem/solution finding. Other aspects that were assessed were the students' reflective practices, which captured students' mastery of the learning process. The assessment of students' learning was a group assessment involving students, teachers, field experts and clients.

4.6.6 Design principle F: Focus assessments of students' learning outcomes more on process, but also on product

Underpinnings - According to Runco (2003), assessments of innovation competence in the educational context should place emphasis on the process instead of the product. A similar recommendation was made by Malaguzzi (1993), who maintained that innovativeness/creativity is more visible when attention is paid to the process and not to the product. Additionally, Simplicio (2000) saw innovativeness/creativity as a method and an approach to thinking. To capture the thinking/cognitive skills involved in the development of innovations, priority must be given to the process over the product. Therefore, the approach to the assessment of innovation competence in students should recognize the development of innovation competence as a learning process. Like any learning process, the development of innovation competence could be seen as a gradual learning process whereby students' thinking and behaviours change as a result of new experiences they have gained (Beghetto, 2005; Root-Bernstein & Root-Bernstein, 2017; Simplicio, 2000). A process-oriented assessment increases students' energy to learn and self-efficacy; overall, a safe learning environment is created that is needed for learning to occur. This approach to assessments following the principles of constructivism gives room for students to find meaning in the various learning activities involved in the three phases of the innovation process (Beghetto & Plucker, 2006; Dezutter, 2011; Sawyer, 2011).

Translation - Design principle F, f*ocus assessments of students' learning outcomes more on process, but also on product*, was translated into an assessment rubric (Appendix G) whereby the observable learning process was captured. Through the created rubrics, students' learning was periodically measured by the teacher to assess what the students knew or did not know about innovation competence, based on the students' submitted products and process observations. Experts' comparative judgments (Appendix H) were elicited via the rubrics concerning the innovativeness and implementation potential of the developed product at all levels. Similarly, the rubric design allowed for self- and peer-assessment and by so doing, a community of learning was created. When used the rubric was used as peer assessment, students saw each other as a resource for understanding and checked each other's work for quality against the established criteria.

4.7 Conditions for successful implementation

In order to ensure the successful implementation of this instructional prototype for innovation competence, certain factors (Hung, 2006) should be taken into consideration. First, the type of tasks, context, scope, format and complexity given to the students all matter. Second, the time frame for implementing all of the teaching and learning activities must be considered. Third, the required learning time and space needed by the students for both the inside the classroom and outside the classroom activities, the individual learning activities, the group learning and assisted learning activities and so forth must all be considered. A reflection activity is a generic activity that should be imbedded into each learning phase with the goal of helping students to achieve optimal learning outcomes (Hung, 2006). By reflecting on the knowledge and skills they have gathered by following the innovation process, students will have the opportunity to organize and integrate their understanding into a more systematic conceptual framework, which enhances their conceptual integration and retention of the subjects they have learnt.

4.8 The innovation competence instructional prototype

Teaching and Learning Activities (TLAs) - Our instructional prototype is an innovative approach designed to help students attain the innovation competencies required to succeed in the workplace of the near future. Our approach is based on the six identified design principles (see Table 1). The prototype will be implemented in bachelor's level courses within Built Environment studies in applied university education. It involves a fundamentally different approach to teaching and learning by which courses intended for fostering innovation competence in students can be orchestrated. Students will be asked to identify innovative problems and develop innovative solutions for Built Environment domain-specific tasks. Some examples of task scenarios are: making homes energy neutral, developing mechanisms and interventions to limit flooding in flood-vulnerable regions, and identifying innovative problems and developing innovative solutions concerning traffic safety in central transportation stations. Task durations range from 2 to 8 weeks depending on year of study and task focus. Below, we describe the unique aspects of our approach.

First, instead of delving right into the subject matter and finding a solution for a given problem, students will be asked to find and analyse two innovations in their fields of study based on current literature and developments. This involves carrying out self-directed learning activities such as reading the instructional and provided materials, watching videos of past innovations and analysing them using diffusion theory, summarizing creative techniques and searching for other supporting learning materials. Students will submit their findings to a collective platform that is accessible by other students. The platform could be an online environment or locally to the teacher, as long as students' products are accessible to other students. At random, students will be asked by the teacher to briefly present an aspect of their findings to the group, followed by questions and discussion sessions. By searching, analysing and presenting past innovations and creative techniques, students will acquire a new perspective on their knowledge potential, requirements for innovation and the various processes employed by innovators in creating innovation. This process will also positively spark their innovation mindset. Therefore, students will create new knowledge beyond what they could learn from any given textbook. Below is a brief description of the teaching and learning activities.

Task - If the definition of innovation is the creation and successful implementation of an original product, idea or service, analyse your selected innovation based on the definition of innovation: 1) Specify and describe what is really new about the innovation; 2) Determine whether the innovation is incremental or drastic and justify your choice; 3) Elaborate upon the likely success factor of the innovation using Rogers' diffusion theory of innovation by way of analysis; 4) Research and provide summaries of four distinct creative techniques.

To ensure that the students possess the right concept about innovation competence, lectures will address the domain-specific knowledge, skills and attitude involved in developing an innovative mindset. The lecture will be aimed at explaining the various strategies involved in finding or identifying innovative questions/problems and developing creative solutions following the innovation/creative process (see Appendix I). Relevant course materials (task, procedures, criteria, assessment rubrics, ILO's, etc.) and students' implicit theories about innovation will also be reviewed and students' theories will be corrected, where necessary.

Next, the students will be required to specify in their logbook their current competencies regarding innovation and, at the end, to compare them with what they learnt during the course. In this way, students are encouraged to take charge of their own learning by articulating their individual associated learning objectives within the broader context of the course. The student will also develop an action plan in order to learn to work systematically and methodically during the course (see Appendices C, D, and E).

Task - Innovators are proficient in their ability to: 1) identify innovative problems; 2) think creatively; 3) demonstrate the fitness of their developed solution for the identified problem. Based on your current knowledge, rate your innovative ability with respect to the three proficiency aspects of innovation using the 7-point scale of 1 (not innovative at all), 2 (slightly innovative), 3 (somewhat innovative), 4 (neutral), 5 (moderately innovative), 6 (highly innovative), 7 (extremely innovative).

Task - Develop an action plan for the three proficiency aspects of innovation for each activity as stated in your main assignment.

Third, the main task or problem scenario to tackle will be presented to students during the first lecture, wherein the context of the task and goal are clearly stipulated. Students will be assigned to individually frame and reframe their own problem, explore the solution space and develop the user criteria via observation, exploration and analysis, following the process stipulated in Appendix I. Students will be encouraged to think individually first, and then bring their input to the group (see, for example, Appendix D, for the procedural description per task). Collectively, both the individual and group input will be used to articulate the problem statements, generate ideas and show possibilities for implementation. By so doing, the construction of students' learning will be encouraged via the individual and group dynamic processes. The main task is aimed at keeping students' efforts aligned with the course objectives and learning outcomes. This will be achieved by structuring the tasks in a predefined format aligned with the innovation process, with firm due dates (see Appendices C and D for task descriptions). The task will also arouse students' curiosity and urge them to be innovators in areas that are of personal interest to them. During the module/course, students will be assigned to identify an innovative problem, develop creative solutions for the problem and demonstrate that the solution is implementable or applicable following the steps and procedures as described (see Appendices D and I). This includes answering the following key questions for each innovation process phase: 1. Did you define and construct a problem that requires an innovative solution? 2. Did you develop conditions and requirements for a good solution to the identified problem? 3. Did you systematically create an original and appropriate solution for the problem? 4. Did you show that your solution solves the problem? 5. Did you provide detailed but systematic reflection about what you learnt per innovation phase using the *Situation-Task-Activity-Result-Reflection* (STARR) method?

Fourth, a lecture on ideation techniques, specifically on scenario-based, divergent and convergent thinking, will be provided to students at the beginning of the ideation phase. A scenario is the heuristic statement designers employ to spark creativity in a systematic way. Students will be introduced to heuristic statements or scenarios from the scenario statements developed and validated by Kramer et al. (2015) or will be asked to develop their own. Examples of heuristic statements from Kramer et al. (2015) are: *utilize opposite surface or mirror; apply existing mechanism in a new way; convert to a second function.* These statements will used in a question form to provoke new thinking at all phases of the innovation process. For instance, a scenario could be: *what solution can be expected if the problem is mirrored? What solution is possible if the existing problem mechanism is applied in a new way? What second function can pair with the existing function of a solution*? The use of the scenarios will not only help students develop novel ideas in a systematic and ordered way, but will also help them to overcome fixation via divergent and convergent thinking during creative sessions.

Fifth, the students will be required to organize creative sessions in which field experts and relevant stakeholders are invited to participate. Students will be assigned to study the rationale, procedures and use of creative strategies such as brainstorming, lateral thinking, and so forth (see Table 4.3, alongside scenario-based thinking). Students will work both individually and collectively during the creative sessions (see Appendix C, section B, idea generation for task specifications and procedure). The creative sessions will conclude with presentations in which the students briefly present their findings to one another.

Sixth, a lecture on implementation, specifically on prototyping, testing, improving and diffusing, will be provided to students at the beginning of the implementation phase. The students will be provided with a number of appropriate exercises to improve their learning about the implementation of innovations. The exercises include researching what method to engage in when developing the solution prototype and what procedure to engage in when testing or demonstrating the fitness of the solution for the identified problem. Student will have to prepare a presentation showing their learning results and complete the reflection form for this phase.

Seventh, the students will be required to organize a network meeting of different stakeholders including field experts in the area of their innovation. Together with the experts and stakeholders, students will review, test, validate, refine, critique and reflect upon the practicality and applicability aspects of the problem and solutions (see Appendix C, section C, implementation for task specifications and procedure). As in the creative sessions, this task will include a presentation in which the students demonstrate and show the applicability of their solution to the audience and develop a mechanism for collecting input from them. Students will be required to complete a reflection form.

Eighth, students will be systematically guided through the specification of task procedures and provision of basic criteria for an acceptable learning product. This strategy as adopted in the task design particularly informs students about how to form a learning organization, self-regulate their learning and collectively leverage each other's competencies to solve a common problem (see Appendix D for procedural descriptions per task).

Ninth, the scaffolding of learning will be realized via reflective practices, the specification of task procedures and basic criteria for acceptable learning products, and group collaboration. They will be required to individually articulate their learning experiences in their logbook using the STARR method. In this way, students' learning progress is made visible and can be identified by the teacher. Students are also able to keep track of their own learning, identify the learning strategies that work, recognize the factors or conditions that led to the learning experience that occurred, demonstrate ownership, commitment, and motivation, and consciously self-regulate their learning. The students will be called upon to reflect on their learning process, the quality of their contributions in the various teaching and learning tasks, the value gained with respect to attaining their individual competencies and learning objectives as well as the overall added value for the learning group. Therefore, the STARR method will be introduced to the students at the beginning of the course.

Deliverables and the assessment of learning processes and products - As noted earlier, innovation competence is a complex competence, which makes the design of its instruction and the assessment that captures the overall learning outcomes of students after going through the learning process challenging for teachers. According to innovation scholars, assessment of innovation competence should capture the process followed to identify a problem, the quality of the articulated problem, the use of creativity throughout the innovation process, the manner in which solution fitness is demonstrated and the degree of innovativeness. All of these require the integrated assessment of the learning process and the learning products developed. The emphasis on the students' learning process and products is challenging for the development of an effective assessment mechanism that includes all teaching and learning experiences. To meet these challenges, we designed assessment procedures, forms and rubrics and incorporated them into the implementation of the prototype.

At the completion of each teaching and learning activity during the course, students will be required to deliver their learning products, either for feedback or for final assessment purposes. The reflection form completed at the end of each teaching and learning activity must also be submitted.

The *first* learning product is the observation, exploration, and analysis of past innovations and the research summaries of existing creative techniques, which is assessed by the teacher at the end of the discovery phase.

The *second* learning product is the current competencies rating in which the student will reflectively self-assess their current and final levels of proficiency, supported with justification, and completing the reflection form per aspect. An action plan also will be handed in to the teacher for review and comments at the beginning of each phase. The action plan will be graded with a GO, GO with conditions, or NO GO.

The *third* learning product involves three interrelated products. The *defined problem statement* is first submitted to the teacher for feedback during the discovery phase and thereafter for final assessment at the end of the course. The self-regulated research exploration of the *solution space* recorded in the students' individual and group logbooks will be assessed by the teacher at the end of the discovery phase. The *user criteria* (statements of criteria, conditions and requirements for an acceptable solution) are submitted to the teacher twice for feedback during the discovery phase, before the final assessment at the end of the discovery phase.

The *fourth* learning product is the *use of scenario-based*, divergent and *convergent thinking*. Here, the assessments of students' learning will take place via teacher assessment using predefined presentation rubrics (Appendix G).

The *fifth* learning product is the ***creative session***. Here the assessments of students' learning will take place via peer and tutor assessment using the predefined presentation rubrics (Appendix G). The students are required to present their learning results to a cluster of student groups. The student group is free in their choice of how to present. It could be a video presentation, a parallel presentation, a single presentation or a forum discussion. Students' products are also collected and summatively assessed by tutors and invited stakeholders using the designed assessment rubric. All assessment forms are designed to improve students' learning, with special attention given to the learning process as observed by the tutor and in students' reflections.

The *sixth* learning product is the *process followed in demonstrating solution applicability and innovation potential.* Here the assessments of students' learning will take place via tutor assessment using predefined rubrics (Appendix G) and experts' comparative assessment of products (Appendix H).

The *seventh* learning product is the *network meetings and the reflection* in which the developed idea or product representing the solution is demonstrated. These learning products will be assessed by the teacher at the end of the meeting and will focus more on the process and reflections. However, the innovative potential of the developed product will be assessed by the experts via expert comparative judgments using our predefined presentation rubrics (Appendix H).

The *eighth* learning product is concerned with the use of *task instructions*, *the self-directed* learning activities and reflective forms. The assessment of these products will be conducted by the teacher at the end of each innovation process teaching phase.

The *ninth* learning product is the overall reflection using the STARR method, in which mastery of the knowledge (content) and skills (process) is expressed. The reflection will be assessed by both the students and the teacher at the end of the course. The students will be asked to propose a grading scheme for evaluating their own work as well as that of their fellow students in their group. For this, they will have to use our predefined comprehensive assessment rubric that shows the categories of work to be assessed along with justifications for the various degrees of achievement. Students will need to articulate the specific grades they believe they have earned according to the rubric. Table 4.4 below shows the assessment procedures for the various deliverables.

Table 4.4 Teaching and learning activities (TLAs) with assessment procedures

TLAs	Deliverables	Assessment procedure
1st	Past innovation and creative techniques	Tutor assessment via process rubric
2nd	Explanation of current competencies	Reflection rubrics
3rd	Problem statement; solution space; user criteria	Tutor assessment via process rubric
4th	Scenario-based, divergent and convergent thinking	Tutor assessment via process rubric
5th	Creative session	Peer and tutor assessment via presentation rubrics
6th	Prototyping, testing, improving, diffusing	Expert comparative judgment via innovative potential rubric and tutor assessment via process rubric
7th	Network meeting	Peer and tutor assessment via presentation rubric
8th	Instruction versus self-directed learning	Tutor assessment
9th	Overall reflection	Overall reflection rubrics

4.9 Conclusion

This article presents six design principles with a matching teaching prototype aimed at helping teachers to create teaching that supports the development of innovation competence in their classrooms. The design principles that formed the basis of the prototype were derived from and linked with validated theories and insights from various authors and fields of study. While these principles are very promising and useful at first sight, their application in diverse practices and settings is still lacking. Does their application lead to better innovation competence among students, are the principles easy and realistic to implement, can teachers do this without too much professional development? Are certain parts more important? Similar questions remain to be answered.

Therefore, more exploratory studies in different educational contexts are needed to help establish the combinations of principles that work best for students and teachers. In the next study, we will conduct an empirical study of the implementation of these principles in the practice of teaching in the Built Environment engineering domain, and at the same time test their efficacy in fostering students' innovation competence.

Although our reflections on the six design principles and our experience during preliminary implementation have indicated that training teachers on the use of the principles offers valuable contributions to students' learning process, this was limited, in that the principles did not address training teachers and how the training improves the innovation competence of students. To prove the core contribution of training teachers, we still have to develop an empirical way of measuring the contribution of teacher training; because of the delayed effect on learning, positive results of teachers' development are only evident some months or years later.

5

Investigating the impact of innovation competence instruction in higher engineering education

Chapter 4 addressed the design and construction of six design principles that formed the basis for a conceptual innovation competence instruction prototype. The prototype consists of diverse teaching and learning activities and assessment mechanisms intended for the promotion of innovation competence education. In its conceptual state, the effectiveness of the innovation competence instruction in fostering students' innovation competence is yet demonstrated. Therefore, the study reported in chapter 5 seeks to understand the extent to which the innovation competence instruction is effective in fostering students' innovation competence. With this goal in mind, this chapter translated the design principles into concrete learning experiences for students and provides teachers with exemplary practices and hands-on activities for the creation of innovation competence-supportive learning environments in the context of Built Environment engineering education.[3]

[3] This chapter is based on: Ovbiagbonhia, A. R., Kollöffel, B. J., & den Brok, P. (submitted for publication). *Investigating the impact of innovation competence training in higher engineering education.*

Abstract

The ability to innovate is a critical competence for engineering students, as work environments and society constantly change. However, innovation competence is often not (explicitly) part of teaching or the curriculum, and teachers struggle to teach their students about this competence. To address this problem, the present study designed a course to develop undergraduate engineering students' innovation competence, based on six design principles. The instruction was nested in a final year course on Built Environments. Paired t-tests showed significant growth in students' self-perceived innovation competence. Analysis of students' innovative products showed that they met the course goals. Students, teachers and other stakeholders also reported positive perceptions of the setup and design principles used in the innovation competence instruction.

5.1 Introduction

For students from all educational domains to function well in today's emerging and ever-changing work environments, educators and scholars have recommended equipping them with the competence to innovate (Avvisati et al., 2013; Beghetto, 2010; Choo, 2018; Keinänen & Kairisto-Mertanen, 2019; Marin-Garcia et al., 2013; Sawyer, 2014; Vila et al., 2012). Regardless of the domain of expertise, higher education is responsible for the development of an innovation-competent workforce (Avvisati et al., 2013; Edwards-Schachter et al., 2015; Trilling & Fadel, 2009; Vila et al., 2012). The European Union agenda for institutions of higher education has also stressed the role of higher education in developing innovation competence in higher education (European Commission, 2017). Although education plays a central role in the development of innovation skills, several studies have indicated that institutions of higher education are not yet meeting this demand (Badcock et al., 2010; Kasule et al., 2015; Tynjälä, 1999; Vila et al., 2012; Virtanen & Tynjälä, 2016). These studies have shown that innovation competence is not yet addressed in actual teaching (Beghetto & Kaufman, 2014; Choo, 2018; Edwards-Schacter et al., 2015; Ovbiagbonhia et al., 2019, 2020) or assessment (Keinänen & Kairisto-Mertanen, 2019; Kivunja, 2014; Marin-Garcia et al., 2016; Passig & Cohen, 2014; Root-Bernstein & Root-Bernstein, 2017). This may be because educators in general do not have sufficient knowledge, experience or access to design principles or instructional strategies to enable them to foster innovation competence in their classrooms (Beghetto & Kaufman, 2014; Ovbiagbonhia et al., 2019, 2020; Passig & Cohen, 2014; Root-Bernstein & Root-Bernstein, 2017). Therefore, there is a need for instructional strategies and design principles to aid teachers in higher education in fostering innovation competence in their classrooms and assessing students' innovation competence (Choo, 2018; Edwards-Schacter et al., 2015; Kivunja, 2014; Ovbiagbonhia et al., 2020). To address this problem, we have developed an innovation competence instruction intervention based on six theoretical design principles (see Chapter 4).

Few studies have investigated innovation competence development in higher education (e.g., Edwards-Schachter et al., 2015; Hu et al., 2016; Kasule et al., 2015; Ovbiagbonhia et al., 2019, 2020). In those previous studies, the authors concluded that learning environments that support the development of innovation competence were either limited, inadequate or non-existent and that innovation competence is not yet a teaching focus in higher education. According to the OECD (2016), institutions of higher education still experience significant challenges in the definition and assessment of innovation competence and teachers lack knowledge of effective pedagogical techniques to stimulate innovation competence. These conclusions reemphasize the need for developing design principles and instructional mechanisms for innovation competence aimed at helping teachers to foster this competence in their students. Such a framework, when anchored in both learning theories and the innovation process, can enhance and support the development of innovation competence in higher education.

To develop students' innovation competence, teachers should engage students in innovative activities during their studies (Keinänen & Kairisto-Mertanen, 2019; Vila et al., 2012). When teachers teach students how to become innovative, the students' belief in their own ability to produce creative outcomes grows (Beghetto et al., 2011). Approaches used for innovation competence instruction in various domains have rarely been integrated into the formal curricula (i.e., R. E. West et al., 2012; Wright et al., 2013). In this disintegrated/informal curriculum approach, teaching and learning for innovation competence usually takes place during one-time summer schools or boot camps outside the formal curriculum. According to Bath et al. (2004), innovation competence is best developed when the teaching and learning activities are integrated within existing curricula as objects of the learning process. In such an integrated curriculum, existing content such as students' learning activities, teaching activities and assessments are redesigned, reorganized or integrated into the existing curriculum, sometimes under different course titles or names (Biggs & Tang, 2011). In integrated curriculum approaches, new lectures are added to fill perceived gaps and small-group learning experiences are integrated with existing lectures (Davies et al., 2013). These curriculum changes result in new innovation competence instruction and learning opportunities or situations that promote and support innovation competence-centred teaching and assessment processes. Observable and measurable learning outcomes are stated, aligned with assessments and describe what a student is expected to know, understand and be able to do at the end of the innovation competence course (Biggs & Tang, 2011; Davies et al., 2013). However, such an integrated curriculum for innovation competence is not common (Keinänen & Kairisto-Mertanen, 2019).

The current study aims to describe the effects of an innovation competence instruction intervention implemented in the existing Built Environment department curriculum at a university of applied sciences in the Netherlands. We explored the key question: *To what extent is the innovation competence instruction effective in increasing Built Environment students' innovation competence?* We focused especially on testing the intervention, based on six design principles, and the learning outcomes for innovation competence. First, this article describes the theoretical underpinning for the six design principles. Next, the instruction is briefly described. Then the data collection and methodology of this study are described. After that, the results of the effects study, using pre- and post-intervention student perceptions, student learning gains after the instruction, and focus group interviews with students, teachers and other stakeholders, are described. Finally, in the concluding section, the main results of the study are summarized and discussed.

5.2 Theoretical framework

In recent years, the study of creativity in educational settings has grown (Beghetto, 2010; Runco & Albert, 2010) but there have been few studies that have thoroughly explored teachers' creativity-supporting practices (Dababneh et al., 2010). The intentional design of innovation competence-supportive learning environments is an area that has not seen much attention in the educational research literature, yet it is profoundly important for supporting creativity in students (Beghetto & Kaufman, 2014; C. Richardson & Mishra, 2018). According to C. Richardson and Mishra (2018), few studies have thoroughly explored teachers' innovation competence-supporting practices (Dababneh et al., 2010). It is critical to investigate how to create innovation competence-supportive learning environments in higher education because, while many teachers may believe that developing students' innovation competence is relevant, they may lack the pedagogical strategies to do so (Chan & Yuen, 2014; Plucker & Makel, 2010; Runco & Albert, 2010; C. Richardson & Mishra, 2018). An essential step in creating innovation competence-supportive learning environments is defining and evaluating innovation competence-supportive principles and instructional strategies (Choo, 2018; Das, 2012; Edwards-Schacter et al., 2015; Kivunja, 2014; Plucker et al., 2004; Ovbiagbonhia et al., 2020; K. Robinson, 2011).

Educators and policymakers worldwide have called for more instructional opportunities to develop students' innovation competence (Avvisati et al., 2013; Beghetto, 2010; Trilling & Fadel, 2009). While the need for developing students' innovation competence is clear, questions remain about how to teach students in ways that foster their learning about the discovery of innovative problems, developing creative solutions and showing solutions' implementation potentials. Scholars across domains have argued that all individuals are capable of developing their innovation competence (Cropley, 2001; Runco, 2004; Sternberg & Lubart, 1995; Torrance, 1962, 1972; Torrance & Myers, 1973; Treffinger et al., 2002). G. Scott et al. (2004), in a meta-analysis of studies on the effectiveness of instruction, found that creativity training helped individuals to develop their innovation competence (as measured in tests of divergent thinking, problem solving, performance, attitudes, and behaviour). They reported cognitive strategies to be most consistently effective in developing creative skills in students across programs. Examples of cognitive strategies in creativity include problem construction, generating novel ideas, idea evaluation, and implementation (Finke et al., 1992; Mumford et al., 1991).

Daly and colleagues reported that engineering courses lacked instruction and assessment focused on problem construction, idea generation, idea evaluation, and implementation (Daly et al., 2014). Explicit instruction is necessary for developing students' innovation competence (Daly et al., 2014). Unfortunately, studies that research the extent to which innovation competence is explicitly taught in higher education are scarce (C. Richardson & Mishra, 2018); studies have revealed that university graduates often lack innovation skills and that institutes of higher education are not adequately preparing students to become innovative (e.g., Avvisati et al., 2013; Kasule et al., 2015; Ovbiagbonhia et al., 2019, 2020; Vila et al., 2012; Virtanen & Tynjälä, 2016). For instance, the study by Ovbiagbonhia et al. (2020) on teachers' beliefs about and perceptions of innovation competence-supportive learning environments revealed that teachers rarely taught innovation competence and that only a minority of the teachers considered teaching for innovation competence relevant. Kasule et al. (2015), in their study of teachers' competence for teaching innovation competence, concluded that teachers were limited as far as fostering innovation competence in their students. Finally, studies on the extent of teaching for innovation competence have mostly revealed that innovation competence activities are rarely emphasized in actual teaching or assessment, regardless of the domain of study (Badcock et al., 2010; Beghetto & Kaufman, 2014; Binkley et al., 2012; Chung, 2011; Kasule et al., 2015; Passig & Cohen, 2014; Ovbiagbonhia et al., 2020; Root-Bernstein & Root-Bernstein, 2017).

According to Kivunja (2014), in order to foster innovation competence in students, a learning environment must train students in solving authentic, real-world problems, reflective practices, openness and collaborative problem-solving skills. Therefore, a need exists for a validated instructional mechanism to support teachers in their efforts to educate their students in innovation competence. The present study intends to evaluate the effectiveness of an instructional intervention that was developed for fostering undergraduate students' innovation competence in environment engineering education.

The use of open-ended, exploratory assignments is a common approach to teaching innovation competence (Daly & Seifert, 2016; Kind & Kind, 2007). An open-ended investigative or inquiry-based approach in science education was found to build higher order cognitive competences such as mental simulation (Cloud-Hanson et al., 2008; Daly & Seifert, 2016; DeHaan, 2009). In engineering, open-ended assignments are used to encourage problem exploration (Daly et al., 2014), and often include teamwork, real-world problems, or real stakeholders (Daly & Seifert, 2016; Dewulf & Baillie, 1999; Stouffer et al., 2004). Open-ended assignments have also been argued to facilitate students' opportunity to think about their own creative processes and to identify ways to improve them (Baillie & Walker, 1998; Daly & Seifert, 2016; Daly et al., 2014; Ishii et al., 2006; Jablokow, 2001).

For the training of complex competences, which includes increasing students' innovation competence (Van Merriënboer & Kirschner, 2007), scholars from various educational fields have suggested the systematic integration of theories (Beghetto & Kaufman, 2014; Davies et al., 2013; Jeffrey, 2006; C. Richardson & Mishra, 2018). In this study, we combined insights from three theories, namely (1) constructive alignment (Biggs & Tang, 2011), (2) the four-component instructional design (4C/ID) model for complex tasks (Van Merriënboer & Kirschner, 2007) and (3) constructivist learning theory (Dezutter, 2011; Sawyer, 2014).

The constructive alignment rationale is the overarching basis upon which the six design principles (see Table 1) were organized as addressing learning goals/outcomes (A), activities (B – D) and assessment (E and F). Following constructive alignment, these three elements should be aligned with each other, so that goals are assessed, teaching activities contribute to realizing the goals, and assessment measures the extent to which the goals are attained (Biggs & Tang, 2011).

According to the 4C/ID model for complex tasks by Van Merriënboer and Kirschner (2007), students should be presented with whole tasks, along with careful design of how the information is presented. This means that designing instruction for innovation competence should be linked with the innovation process (Wright et al., 2013), in order to describe the various partial tasks involved in the learning process. Innovation competence can be achieved if it is taught following a systematic innovation process (Van Merriënboer & Kirschner, 2007; Wright et al., 2013). Amabile (1996) and others have identified stages or processes experts go through in arriving at an innovation.

Analysis of these processes revealed three phases of innovation upon which teaching can be based: opportunity or problem discovery, creativity or ideation, and testing or solution implementation. Problem discovery involves the teaching and learning of how to identify, structure and evaluate the opportunity within the context of a problem through creative exploration, creative questioning, research and reflection (Basadur et al., 1982; Cross, 2002; Dym, 1994; Lumsdaine et al., 1999; Martindale, 1999). The ideation or creativity phase involves using different techniques to generate, evaluate and judge solutions for the defined problem (Lewis & Zuga, 2007; Voland, 2004). Creativity requires both divergent and convergent thinking skills (Amabile, 1996; Dyer et al., 2009). During the divergent stage, as many solutions as possible are generated by thinking in scenarios or thinking outside the box (Cross, 2002; Koen, 1985).

The convergent stage is a solution reduction process where the defined performance/user criteria are used to select the best possible implementable solution to the problem (Dyer et al., 2009; Lumsdaine et al., 1999). Solution implementation is entirely an iterative testing phase, where the emerging solution is validated, refined, restructured and presented. During this phase, new rounds of creative problem-solving skills may be required (Belski, 2009; Lumsdaine & Binks, 2006) and it also involves reflective practices (Cross, 2002). In this phase, prototypes, models, calculations or simulations are developed as objects of study and modes of idea generation and solution evaluation.

Scholars have stated that constructivist learning principles promote innovation competence, in that they facilitate the use of the students' own active cognitive abilities (Gatlin, 1998), and students are encouraged to be active participants in their learning, to self-regulate their learning process and to construct learning through social interaction. The goals of constructivist learning are innovative thinking, understanding and use of knowledge, self-regulation and mindful reflection (Driscoll, 2005). According to Jeffrey (2006), constructivist learning is characterized by teaching focused on development of personal relevance making, student ownership of knowledge and control of learning processes, and emphasis on the relevance of innovation. Three essential strategies are often employed to create a constructivist learning environment intended to support the development of innovation competence in students (R. E. West et al., 2012; Wright et al., 2013). First, learners are engaged in authentic tasks. Authentic tasks are 'real world' or contextualized tasks that are personally relevant or interesting to the learner (Duderstadt, 2008; R. E. West et al., 2012). Second, learners are encouraged to actively construct their understanding and create their own representations, instead of receiving information from a teacher (Crawley et al., 2007; Dyer et al., 2009; Wright et al., 2013). Third, learners are given the opportunity to engage in discussion, collaboration, and reflection (Dyer et al., 2009; Grasso & Burkins, 2009; Wright et al., 2013). In order for the students to practice innovation competence in these authentic circumstances, it is necessary that the learning environment incorporate all three of the above-mentioned parameters.

As such, the six design principles (Table 5.1) were derived from the integration of insights drawn from the above theories, namely the curriculum instruction model for complex competencies - the 4C/ID model (Van Merriënboer & Kirschner, 2007), which in this case used the simplified innovation process (Amabile, 1996; Ovbiagbonhia et al., 2019; Wright et al., 2013), constructive alignment (Biggs & Tang, 2011), and constructivism (Beghetto & Plucker, 2006; Dezutter, 2011; Sawyer, 2014). These theories are interconnected and build upon each other in this dissertation study. As such, each design principle can be linked to one or more of the theories. Therefore, the main aim of this study was to understand the effect of this instruction on increasing Built Environment engineering students' innovation competence.

5.3 Research questions

Following the reviewed literature, three research questions relating to the instruction's effectiveness guided this study:

1. To what degree did students perceive themselves to have improved their innovation competence by participating in the innovation competence instruction?
2. To what degree did students' innovation deliverables (course outcomes) meet the course goals?
3. What aspects of the instruction did assessors perceive to have promoted the development of innovation competence and to what degree did assessors feel that students acquired innovation competence?

Table 5.1 Design principles innovation competence instruction

Aspect/reference	Design principle
Goal: Teaching and learning goal (Biggs & Tang, 2011; Binkley et al., 2012; Van Merriënboer & Kirschner, 2007)	Define holistic but measurable learning goals.
Explicit teaching: Teaching and learning sequence (Beghetto & Kaufman, 2014; Biggs & Tang, 2011; Fraser, 2012; Lim and Sato, 2006; Van Merriënboer & Kirschner, 2007)	Incorporate constructivist learning principles in the learning environment.
	Base teaching on the innovation process sequence.
	Teach sound creative techniques.
Assessments: Students' learning outcomes (Beghetto & Kaufman, 2014; Biggs & Tang, 2011; Binkley et al., 2012; Fraser, 2012; Lim & Sato, 2006; Marin-Garcia et al., 2016; Malaguzzi, 1993; Runco, 2007; Van Merriënboer & Kirschner, 2007)	Ensure that assessments of students' learning outcomes are simple to use, systematically aligned with the learning activities, and concise but comprehensive enough to capture relevant aspects of innovation competence. Assessments of students' learning outcomes should focus more on process than on product.

Definition

The following intended learning outcomes were defined for innovation competence instruction:

a. The student can *systematically discover the problem gap* in each problem context.
b. The student *can create an original and appropriate solution* to the articulated problem/question, following an established creative procedure/process.
c. The student can design and implement an experimental plan intended to *evaluate the effectiveness or shortcomings of the generated solution(s)* to problems.

Constructivist learning principles:

a. *Personal relevance* - use of daily experiences as a meaningful context for the development of knowledge in the classroom.
b. *Uncertainty* - challenging the myth or students' beliefs about independent objective reality in the learning environment.
c. *Student negotiation* – promote knowledge building through teacher–student and student–student negotiation.

Innovation process:

a. *Problem discovery phase* –students are taught how to raise and define innovative questions or problems.
b. *Ideation phase* – the teaching and learning activities focus on how to generate creative solutions following a systematic process and using sound creative techniques.
c. *Implementation phase* – involves the teaching and learning of test and evaluation methods in order to determine the extent of solution appropriateness or implementation.

Creative techniques:

Students are taught how to deploy sound creative techniques such as creative problem-solving, brainstorming and scenarios, lateral and vertical thinking to avoid fixation and develop creative ideas.

Three assessment rubrics (for both summative and formative use):

a. *Tutor/peer assessment rubric* focusing on students' learning process;
b. *Reflection rubrics* focused on students' reflective practices.
c. *Experts' comparative judgment rubrics* focused on the innovative potential of students' products.

Assessment of learning: This was achieved by focusing assessments on learning mastery rather than on test scores or performance. The assessments of students' learning centred around growth, team development, mastering of skills and mastering of the elements of the innovation process.
In this way, a student-centred environment was created, students' stress was reduced, and a growth mindset was encouraged.

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5.4 Method

5.4.1 Course design and sample

The course was open to all final-year students who were working on their final thesis in a university of applied sciences Built Environment department. The instruction aimed to develop students' innovation competence in Built Environment engineering contexts. This included analysing problems from multiple perspectives, articulating the problem, creating an original and appropriate solution for the articulated problem/question by following an established creative procedure/process, and demonstrating the effectiveness or shortcomings of the generated solution(s) for problems (Table 5.2 provides an overview of the course structure).

The course was a 5-credit course that served as a preparatory course to support final year students in developing their innovation within their final year thesis. The present study reports on the course that occurred in the first semester of the 2018–2019 school year, in which 53 students (9 groups) participated. However, data analysis was based on 46 students, due to the fact that some students either did not complete the post-test survey or provided no identification information, so that pairing pre-test and post-test responses became impossible.

Participants were in their final year in one of the following Built Environment majors: architectural engineering, building engineering, civil engineering, or special planning. Ages ranged from 20-31; however, most participants were between 20-25 years old. Approximately 19% of the participants were women and 81% were men. Table 5.3 gives a breakdown of the number of participants from each major that was represented.

Table 5.2 Innovation competence instruction course structure

Time	Content & teaching methods	Tasks
week 1	Introduction	Not applicable
	Pre-test	Online survey
	Formation of teams	
weeks 2-3	Learning outcome 1: Discovery of innovative problems	Articulate the initial problem statement Present and probe the initial problem statement in your review team
	Lectures	Organize network meetings
	Workshops	Articulate the final problem statement Present and probe the final problem statement in your review team Articulate the initial user criteria Present and probe the initial user criteria in your review team Articulate the final user criteria Present and probe the final user criteria in your review team
week 4	Learning outcome 2: Generation of innovative solution Lectures	Organize ideation sessions & network meetings Record the solution options, including a process report Probe the solutions using the user criteria, adjust the user criteria if need be
	Workshops	
weeks 5- 6	Learning outcome 3: Implement/experiment with design	Organize implementation sessions & network meeting Evaluate based on the user criteria, modify and reflect on the solution(s). iterate if necessary
	Lectures	Report on the implementation process
	Workshops	
Week 8	Post-test	Online survey

Table 5.3 Number of participants per study major

Study major	Number	Percentage
Architectural engineering	6	11.3%
Building engineering	23	43.4%
Civil engineering	17	32.1%
Special planning	6	11.3%
Other	1	1.9%
Total	53	100%

For data analysis, n = 46.

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Students were assigned at random to 9 groups of six students each. Students had different graduation directions and worked on different topics within the groups. Examples of topics were developing a model for making homes energy-neutral; developing strategies for combating material wastage during building construction; developing methods to facilitate adoption of the BIM (Building Information Model) by workers at construction sites.

The course was implemented within the existing curriculum and used open-ended tasks. The students worked on their tasks individually as well as in groups and received coaching from a teacher. The coaching sessions were provided for each group. Tasks involved coming up with an innovative question from a problem posed by an external client, developing creative solutions and demonstrating that the solution developed could be implemented for that real-world problem.

5.4.2 Development of innovation competence instruction

The instruction was developed following the educational design research core processes of McKenney and Reeves (2019). Based on the recommendations offered by McKenney and Reeves (2019), the training development study took place through a series of iterations. In total, three iterations were conducted at three universities of applied sciences in the Built Environment engineering domains, one iteration at each university of applied sciences. These iterations are briefly described below. The final version of the instruction was tested and evaluated at a different university of applied sciences than those at which the iterations were conducted.

To explore and analyse the current situation concerning innovation competence at universities of applied sciences, a preliminary study was conducted to map students' perceptions of the existing learning environment aimed at the teaching of innovation competence and of their own innovation competence (see Ovbiagbonhia et al., 2019). Teachers' beliefs about the relevance of innovation competence and their perceptions of the existing learning environment aimed at the teaching of innovation competence were also investigated (see Ovbiagbonhia et al., 2020). Based on the findings from those investigations and following the earlier mentioned theories, design principles for innovation competence instruction were developed, as well as a prototype of the training.

Three iterations or pilots were conducted to test the prototype. The first pilot was done to test the working of design principles A (learning goals) and B (constructivist learning principles). During this initial iteration, we developed various tasks for students to perform. We observed that students had some difficulties in formulating problem statements from an observed problem and raising innovative questions. These aspects were revisited in the instructional design. The second pilot led to more extensions and detailing of the design principles around coming up with an innovative problem statement, which resulted in clearer steps. Students needed more detailed descriptions of the process, specifications and criteria for the key elements of the expected deliverables, such as user criteria. These aspects were tackled via mini lectures on the use of divergent thinking techniques and the use of design heuristics to avoid fixation. The third pilot led to more tightening of the various deliverables and the process, and the use of mini lectures to teach strategies. The fourth and final version of the intervention is the one that is tested here in the present study.

Table 5.4 Innovation competence instruction activities and content

Teaching and learning activities	**Procedure and content**
Teaching activities	Content
Workshops	Group work on domain-specific innovation: study, discuss and clarify the innovativeness of domain-specific innovation based on the five characteristics of innovation (Rogers, 2003).
	Individual exercise: study, discuss and clarify how to conduct observational and exploratory studies.
	Individual exercise: study, discuss and clarify how to analyse data from the observational and exploratory studies.
	Individual exercise: demonstration of problem-identification scenarios.
	Individual exercise: study, discuss and clarify how to articulate problem statement.
	Group work ideation session: demonstration of uses of heuristic statements (scenarios).
	Group work ideation session: study, discuss and clarify how to use scenario thinking in developing innovative/creative ideas.
	Group work implementation session: study, discuss and clarify how to design the solution implementation process.
	Group work implementation session: study, discuss and clarify how to test/validate/judge/reflect on the solution implementation process.
Coaching	Teachers/students weekly coaching meetings during task execution.
	Online help desk.
	Group discussion forum. Students could send questions to their teachers. The question and teachers' feedback were viewable by all students in the forum.
	Group work interaction and reflective discussion forum.
Mini-lecture	Innovation competence and process theories.
	Creative strategy and scenario (heuristic statements) uses.
	Complex tasks for each innovation phase, their procedures and criteria for an acceptable product.

Table 5.5 Innovation competence instruction student activities, procedures and content

Learning activities	Procedure and content
Identifying innovative problem	Template with procedural description for conducting problem observation, exploration and analysis systematically.
Problem statement	Template with procedural description for developing a good problem statement description.
User criteria	Examples of user criteria.
Creative session	Procedural description for organizing creative session.
Solution fitness	Procedural description for the design and implementation of test protocol supported with real product design examples.
Reflective practice	Template for each student to support reflection on learning experiences

Table 5.6 Innovation competence instruction student deliverables and assessment procedures

Phases	Deliverables	Assessment procedure
1st	Problem statement, solution space, user criteria	Tutor assessment via process rubric
2nd	Scenario, divergent and convergent thinking	Tutor assessment via process rubric
3rd	Creative sessions	Peer and tutor assessment via presentation rubrics
4th	Implementation sessions: prototyping, testing, improving, diffusing	Experts' comparative judgment via innovative potential rubric and tutor assessment via process rubric
5th	Network meeting	Peer and tutor assessment via presentation rubric
6th	Instruction versus self-directed learning	Tutor assessment
7th	Overall reflection	Tutor assessment via the overall reflection rubrics

The instruction provided support to students in the form of lectures, workshops and coaching. At the start of each task, support related to an intended learning outcome was provided by domain experts, specialists in the task topic. The expert lecturers presented the problems to students and graded their reports (grades were given on a scale from 1 to 10). The researcher and a guest lecturer were the only experts/tutors. Each tutor was assigned to support half of the teams. An online help desk was also provided, where students were encouraged to pose questions to the tutors or contribute to discussions. Students' deliverables were presented in a report and logbook and were graded by the two assessors (expert lecturers). A total of six pairs of expert lecturers assessed students' deliverables. Reports and logbooks were assessed on a group basis using the designated assessment rubric. Tables 5.4, 5.5 and 5.6 provide details about the instructional components and assessment procedures. During the instructional session, students were required to work on different tasks that were aligned with the three intended learning outcomes (see Table 5.1, design principle A, for the intended learning outcomes).

5.4.3 Research instruments

The research was designed to provide answers to the three research questions. For the purpose of answering the first research question, students were required to complete a pre- and post-test survey (Appendix J). Eight items were used to represent perceived mastery of the three intended learning outcomes (ILOs) taught during the course. Responses to forced-response survey items (using a seven-point scale) were averaged and reported descriptively, comparing pre-test with post-test averages. Cronbach's α calculated for the three intended learning outcomes combined was .82. Two items measured perceived mastery of ILO 1 (understood the assignment's purpose), with a Cronbach's α of .60. Three items measured perceived mastery of ILO 2 (thought in scenarios to generate ideas), with a Cronbach's α of .63 and three measured perceived mastery of ILO 3 (operable implementation plan was designed), with a Cronbach's α of .60.

The second research question was centred around students' deliverables, assessed via a rubric. An evaluation of students' innovation competence outputs after completing the course was conducted to assess the effectiveness of the instruction. Students' products were evaluated according to the innovation competence matrix aligned with the three intended learning outcomes. The list included 22 items (Appendix L), distributed over the three intended learning outcomes. For all ILOs combined, Cronbach's α was .98. Eight items measured ILO 1, with a Cronbach's α of .96. Similarly, eight items measured ILO 2; Cronbach's α was .94. Six items measured ILO 3, with a Cronbach's α of .97. A pair of two experts used the 22-item matrix to joint grade students' products on a 5-point scale. In total, six pairs of experts participated in the grading process. Correlational analysis revealed high correlations (i.e., above .80) between the individual ILOs, resulting in the creation of the combined ILO scale.

To answer the third research question, focus group discussions with stakeholders (students and teachers) were conducted at the end of the last class session of the course. The group interview was aimed at eliciting stakeholders' opinions about the course design and content. Three groups of students were invited to participate in the group discussion. The discussions with the students took place before the students received their final grade from the assessors. The group interviews with the student groups were conducted separately per group, and lasted one hour, in a quiet and comfortable environment (Litosseliti, 2003). The discussions were audiotaped, and field notes were taken (Hansen, 2006). Examples of the questions asked were: 'What is your opinion about the innovation competence instruction course?', "Was it possible to formulate a good description of the problem using the procedure provided?" (Appendix K). One pair of teachers from the six who graded students' deliverables were also interviewed about the innovative nature of students' work.

The data collected from the focus group discussions were analysed by the first author using thematic analysis (Lincoln & Guba, 1986; J. A. Smith et al., 2009). Students' data were organized by connecting statements to the design principles (Morse & Field, 1995), while teachers' data were also organized by connecting statements to the three learning goals (Morse & Field, 1995).

5.5 Results

5.5.1 Research question 1: Students' perceptions of the degree to which their innovation competence improved by participating in the innovation competence instruction course

Self-assessment of students' learning showed that they perceived themselves to have made significant improvement on all three ILOs. Paired-samples t-tests were conducted to compare students' pre-test and post-test scores. Students' increases in scores for all three individual ILOs were statistically significant ($p < .01$). Improvement in scores for the combined ILOs was also statistically significant ($p < .01$). The magnitude of the differences in the means was very large (see Table 5.7).

Such results indicate that students overall agreed that they had learned to raise innovative questions, devise creative solutions to the problem identified and show that the developed solution for the problem was appropriate after the innovation competence instruction, while they, in general, disagreed that they could do this prior to the instruction.

Table 5.7 Paired samples t-test table

Survey item Pre: Based on regular lessons, I learned to....... Post: Based on the innovation competence instruction lessons in year 4, I learned to	Number of items	Pre-test M	Pre-test SD	Post-test M	Post-test SD	t	p	η^2
All intended learning outcomes (ILOs 1-3)	8	2.39	.48	4.90	.82	-19.58	< .01	.81
Intended learning outcome (ILO) 1 – problem	2	2.53	1.09	4.97	1.18	-14.42	< .01	.70
Intended learning outcome (ILO) 2 – ideation	3	2.44	1.00	4.68	1.30	-15.06	< .01	.72
Intended learning outcome (ILO) 3 – implementation	3	2.23	1.07	5.20	1.11	-16.51	< .01	.75

These items used a 7-point response scale where 7 = strongly agree and 1 = strongly disagree. Pre-test: n = 46; Post-test: n = 46.

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5.5.2 Research question 2: The degree to which students' products met the course goals

To answer the second research question, grading of students' final products by teachers at the end of the semester revealed that the majority of students were graded above 3 on a scale from 1 (lowest) to 5 (highest) for the combined ILOs. Table 5.8 presents the teachers' grading of students' deliverables. The assessors judged the majority of students' deliverables satisfactory. One student's work was considered poor and 2 students' work was considered excellent by their assessors. Table 5.8 displays the breakdown of students' overall grading.

Table 5.8 Overall grading of students' innovation competence deliverables

Grade	Number	Percentage
2	1	2.2%
3	27	58.7%
4	16	34.8%
5	2	4.3%
Total	46	100%

Grading scale: 1 = bad; 2 = poor; 3 = satisfactory; 4 = good; 5 = excellent.

On average, the grading of the ILOs was basically identical (Table 5.9). Standard deviations revealed little variation in students' individual grades per ILO. The scores for the items measuring ILO 1 showed that students understood the assignment's purpose, identified the core problem, conducted relevant problem analysis and displayed self-management by working methodically towards the targeted goal, as the assessors rated these items as good. Similarly, the scores for items measuring ILO 2 showed that students thought in scenarios to generate original and appropriate solution ideas, drew conclusions on relevant aspects, created scenarios based on the developed user criteria and identified risk aspects. However, reflective practices were graded relatively lower by the assessors, especially for the items measuring ILOs 2 and 3.

Table 5.9 Mean average scores of students' innovation competence deliverables per ILO

Intended learning outcome (ILO)	Items	α	M	SD
All ILOs combined	1-22	.98	3.42	.61
ILO 1	1-8	.96	3.49	.67
ILO 2	9-16	.94	3.40	.62
ILO 3	17-22	.97	3.36	.60

Grade score scale: 1 = bad; 2 = poor; 3 = satisfactory; 4 = good; 5 = excellent. N = 46.

5.5.3 Research question 3: Stakeholders' perceptions of the performance aspects of the innovation competence instruction

The focus group interviews were transcribed and analysed. In this case, the analytic themes were the design principles, and the analysis involved relating students' opinions about the instruction to a design principle. Themes that could be consistently identified in all three groups of respondents are presented below, along with illustrative quotes.

Three intended learning outcomes formed the basis for the instruction. One student commented as follows on the effectiveness of the aligned learning outcomes:

- I find it useful to know more about the process of innovation and to improve my competence in this regard for the future workplace. As a future structural engineer, I am expected to be able to come up with and implement new solutions. (Student 23 - personal relevance)

The innovation competence instruction was anchored on constructivist learning principles that were greatly valued by students, as these quotes show:

- This course helped me to be able to break down my assignment and focus on the most important aspects of the question. (Student 9 – define holistic but measurable learning goals)
- In this course I find it very interesting to learn to reason differently about things outside my professional setting. (Student 11 – uncertainty)

- We were not combining ideas but questioning each other's solutions before getting the final results. The other student must convince the group by clear evidence. I did not reason like this in any of my previous courses. (Student 25 – student negotiation)

Students felt supported by the steps and procedures defined in the tasks for coming up with an innovative question or problem, and the creativity and implementation sessions. They were confident that the procedures did not hinder their ability to think creatively or generate innovative ideas. The students also reported confidence in transferring the knowledge gained from the instruction to other areas of study. The following quotes illustrate their positive perceptions of these aspects:

- Using the various procedures defined in the tasks, we succeeded in generating several scenarios to arrive at different creative solutions. (Student 13 – innovation process sequence)
- Yes, I can transfer the knowledge I gained from this course to other domains. For example, in developing my advisory report. (Student 9 – knowledge transfer)

Creative thinking is the backbone of innovation; as such, mastering creative techniques was of high importance. The following exemplary statement reveals one student's perception of the organized creativity sessions:

- …learned that I can remove the vagueness in a problem (in this case defining the problem) by applying a structured creative method. (Student 4 – creative techniques)

Students appreciated the sessions that were organized in small groups. They felt that the small group discussions helped them to understand the role of group creativity in solving problems, as illustrated by the following quote:

- The small group sessions were very effective. There were possibilities for developing ideas and discussing the problem. (Student 42 – instruction organization)

The above student reflections about the effectiveness of the instruction indicated that students had positive impressions of the effectiveness of the design principles for improving their innovation competence. Overall, students were satisfied about the course structure as arranged around the simplified innovation process. The students provided positive comments about the lecturing in general and about the feedback they received during small group meetings. They felt that their innovation competence improved by participating in the instruction.

Almost all students mentioned positive experiences with the instruction. Students were satisfied with the information presentation in the various tasks and experienced the various procedural descriptions as useful guides for their execution of the learning activities. This shows that the design principles and the three aligned learning goals were sufficient for stimulating development of students' innovation competence.

We did not gather students' reflections concerning design principles E and F, because we did not want their impressions about the instruction to be influenced by the grade they received. However, two of the 12 assessors were interviewed separately about the instruction process, and all assessors' written justifications for the grades they assigned to students' outcomes were also analysed and organized according the learning outcomes. When asked about the improvement they perceived in students' attitude, they commented as follows:

- I noticed that the innovation assignment stimulated the students to conduct research, which fits in well with the final year assignment. (Teacher 1 – task approach)
- The students showed a lot of responsibility and risk taking this year. (Teacher 2 – risk taking)
- I noticed this year that the students have been activated to seek information outside the group through brainstorming sessions. (Teacher 1 – collaboration)
- I think the innovation instruction improved students' overall knowledge about solving complex problems. For example: someone took the initiative to call in a financial expert. (Teacher 2 – innovation competence)

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Like the students, the teachers were also positive about students' attitudes towards the tasks. Their comments supported the effectiveness of the design principles and learning outcomes. According to the teachers, the ability to take calculated risks and good group dynamics among the students were visible in the students' learning behaviours.

All assessors gave written justifications for the end grades they assigned to students' deliverables. In general, teachers appreciated students who structured and carefully presented their concepts in a systematic way:

- …gets quality that is visible in steps in itself (vision, strategy, concepts, baseline measurement, measures), a practical application (in client's interest) completed with relevant conclusions and recommendations, and substantiated. (Assessor 5 – thought in concepts and methodical)

Other aspects teachers valued in students' problem statements were the level of analysis and exploration of data leading to the stated problem:

- …thorough problem analysis and research exploration conducted. (Assessor 11 – problem analysis and exploration)

All teachers appreciated creativity in students' work. In fact, creativity played a major role in teachers' judgements of students' work:

- …integrated and creative approach to research and development of products. (Assessor 7 – ideation)

Just a handful of teachers used the implementation potential of students' products as a justification for the grade they assigned to students' products. However, most teachers referred to whether the client was satisfied or not with the solution the student generated for the problems:

- Your documents are thorough pieces in which you show yourself to be precise and careful. In our conversations with your client, we heard and saw the very positive comments regarding your functioning there. (Assessor 2 – implementation)

Students' ability to reflect on their product was valued by all teachers in their justification of students' grades:

- The student also makes a good and relevant connection between the action plan, the user criteria and differently conceived solutions. (Assessor 6 – reflective practices)

In general, most of the assessors expressed satisfaction with students' methodical approach to problem identification and solution generation. Assessors expressed satisfaction about the students' products, especially when the client deemed the solution useful. Reflective practice was also an area assessors talked about in determining students' grades.

5.6 Discussion and conclusion

This article aimed to describe the effects of an integrated course implemented in the existing Built Environment curriculum, by mapping students' outcomes and stakeholders' perceptions. It examined the assessments of students' deliverables and analysed assessors' justifications for grades. In this way, important information concerning the effectiveness of the six design principles and three learning goals was revealed. Providing innovation competence instruction for fourth-year bachelor's students, who are close to graduation and about to make the transition to working life or further studies, will help to show how to develop effective innovation competence education and thus to respond to the demands of working life and an innovative society.

The study contributed to better understanding of how the instruction that was integrated within the existing curriculum fostered students' innovation competence. The conclusions based on the three research questions can be summarized under two main headings, namely: (1) perceptions of the instruction's effectiveness and the assessments of students' deliverables with respect to the degree to which the learning outcomes were attained and (2) the effectiveness of the design principles. According to students' pre- and post-test self-reports, the instruction promoted their innovation competence. This result is consistent with the studies by R. E. West et al. (2012) and Wright et al. (2013), where students also reported positive views of their competence after completing training that supported innovation competence. The positive results from students' self-reports demonstrated the effectiveness of creating a learning environment that supports innovation competence for enhancing students' innovation competence (Amabile & Pratt, 2016; Davies et al., 2013; C. Richardson & Mishra, 2018). They also revealed the role and relevance of anchoring the instruction to relevant theoretical insights (Beghetto & Kaufman, 2014; Jeffrey, 2006; C. Richardson & Mishra, 2018). Amabile (1996) stressed the need for discipline-based knowledge and skills for creative thinking education.

The results of the current study were consistent with findings from other studies related to improving students' innovation competence (Horng & Hu, 2009; Ko, 2012). For instance, Horng and Hu (2009) used quantitative and qualitative analyses and found that teaching of the culinary creativity process impacted culinary creativity performance. Horng and Hu's (2009) study also demonstrated that both students' culinary creativity process and their performance could be significantly improved by explicit teaching of culinary arts using the experimental curriculum.

Students' qualitative reflections about the instruction showed that students were positive about its effectiveness. Students provided positive comments about the course's task structure, the course alignment and the constructivist nature of the learning environment. Similarly, most of the assessors expressed satisfaction with the students' methodical approach to problem identification and solution generation. Both students and assessors/teachers appreciated the manner in which the various tasks were structured, demonstrating the special position of design principle C – base teaching on the innovation process sequence. Similarly, the mode of collaboration within the instruction, students' risk-taking attitude, problem analysis and exploration skills were prominent comments made by many respondents. The lectures and feedback on the ideation process were also valued by respondents. These comments show that design principles B – constructivist learning principles, C – base teaching on an innovation process sequence, and D – teach sound creative techniques, were, in the stakeholders' view, the most influential principles for developing students' innovation competence.

This study enriches the literature on education that supports the development of innovation competence, and it is integrated within existing undergraduate education by filling the gap regarding design principles and instructional strategies to foster innovation competence in classrooms.

Although previous studies have suggested ways to create learning environments that support innovation competence (Davies et al., 2013; C. Richardson & Mishra, 2018), there is less empirical evidence for guidelines establishing how to create such learning environments. Thus, this study responds to scholars' call to provide clear guidelines for creating learning environments that support the development of innovation competence (Bath et al., 2004) by empirically testing the effectiveness of the instruction in fostering undergraduate students' innovation competence.

Additionally, previous studies have suggested ways to promote students' innovation competence by solely aligning its teaching with an innovation process, often disconnected from the existing curriculum (R. E. West et al., 2012; Wright et al., 2013) or focusing on an aspect such as the ideation process (see, for instance, Kramer et al., 2015). Few empirical studies have integrated students' innovation competence instruction within the existing curriculum of final year undergraduate education (Bath et al., 2004; Davies et al., 2013). The present study provided clear evidence of the effectiveness of the instruction by demonstrating the positive influences of instructing undergraduate students on innovation competence.

Furthermore, this study represents one of the first attempts to simultaneously examine distinct theoretical concepts from different backgrounds to develop an innovation competence instruction program. Specifically, by drawing on the constructive alignment model, the 4C/ID model and constructivism, the findings extend the current understanding of innovation competence learning goals, innovation competence instruction alignment and sequences, and innovation competence assessment. In recent years, scholars from different domains have argued that anchoring innovation competence education on constructivist learning theory can positively enhance students' innovation competence (Amabile, 1996; Driscoll, 2005; Ertmer & Newby, 1993; Fraser, 2012; Kwan & Wong, 2014; Michael, 2006; Ovbiagbonhia et al., 2020; Root-Bernstein & Root-Bernstein, 2017; Vila et al., 2012). Kivunja (2014) stated that the key to teaching innovation competence lies in creating high quality learning environments in which learners can solve real-world problems and be creative. The study by Hu et al. (2016) also showed that an innovation-directed curriculum improves students' innovation competence. Nevertheless, few studies have explored the possibilities of various theories simultaneously. This study deepens our understanding about how to foster students' innovation competence within existing curricula, in which innovation competence instruction can increase students' ability to identify innovative problems, to develop innovative solutions for the identified problems and to demonstrate the fitness of the solutions.

Educating students' innovation competence is still a major challenge for teachers in various domains, and determining how to train students in innovation competence remains the subject of scholars' attention. Past studies have shown that when teachers are provided with educational hands-on tools, they tend to better assist students to develop innovation competence (Abd Hamid, 2006; R. E. West et al., 2012; Wright et al., 2013). This study delivered an empirically tested innovation competence instructional regime for fostering undergraduate students' innovation competence that can be applied across educational domains. The direct educational implication is that educators can foster students' innovation competence by building on the products of this research in the area of setting measurable learning goals, adopting constructivist learning principles, basing teaching on the innovation process sequence, teaching sound creative techniques, employing simple, systematic and aligned assessments, and focusing assessments more on process than product. However, a learning environment that supports the development of innovation competence requires a move from teacher-centred to student-centred teaching and learning. Student-centred teaching and learning require the teacher to have both content knowledge about pedagogy and theoretical knowledge about innovation competence (Konst & Scheinin, 2018; Trilling & Fadel, 2009). To achieve this, professional development is required for teachers in the area of pedagogical content knowledge related to innovation competence and theories about supporting innovation (Keinänen & Kairisto-Mertanen, 2019; Kivunja, 2014). In this respect, the role of university management in encouraging and facilitating teachers to move towards innovation competence education cannot be overemphasized.

In general, this study demonstrated that innovation competence is teachable and that universities can focus on instructing their students for innovation competence in practice, instead of demanding that students be innovative without explicit curricula for innovation competence. The findings of this study have important implications for future practice, not only when it comes to developing effective mechanisms for innovation competence instruction, but also in contributing to creating an innovative workforce for society. However, there are limitations to the generalizability of the findings of the current study, in that the study was conducted in only one area of study. We suggest replicating this study in other educational domains to improve its generalizability. This study also relied heavily on self-assessments. Past studies have reported a possible bias for self-assessments, in that respondents often tend to present themselves in a more favourable light (Vazire, 2010; Zell & Krizan, 2014), although there are numerous arguments supporting the use of self-report, such as the better quality of information respondents possesses about themselves (see, for instance, Paulhus & Vazire, 2007). Similarly, students' deliverables were evaluated using expert assessment, which according to previous studies, can be elusive and inexact (Ward et al., 2002; Woolley et al., 2004). However, the study by Butter and van Beest (2017) validating an innovation competence assessment tool showed reasonable correlations between the self-assessment scores and external indicators of innovation competence. The number of participants in this current study can be judged as sufficient, but future research could pursue further development of the instruction by using more participants, conducting longitudinal studies from the first year to the final year and devising more extensive and refined questionnaires. Additionally, further studies could assess the long-term effects of innovation competence instruction, for instance, how students transfer knowledge gained during their education to practice. The study is also limited in terms of implementation; further studies could devise ways to train teachers, as most teachers find teaching innovation competence difficult (Keinänen & Kairisto-Mertanen, 2019).

In the current study, both students and teachers reported positive perceptions about the innovation competence instruction. The core responsibility of higher education is to develop participants for the workforce who are competent in resolving problems innovatively regardless of domain (Avvisati et al., 2013; Edwards-Schachter et al., 2015; Trilling & Fadel, 2009; Vila et al., 2012). Overall, findings of this thesis suggest optimistic conclusions in terms of the contribution the design principles make to innovation competence education and the light it shared regarding how to support and explore innovation competence-supportive learning environments across domains.

6

Summary, conclusions and discussion

This chapter presents an overview of the results of the four studies, general conclusions and discussion thereof, and discusses the scientific and practical implications of these findings.

6.1 Revisiting the research: goals and key findings

Fostering students' innovation competence in higher education is very relevant in current times. However, research has shown that higher education learning environments rarely explicitly support the teaching and development of students' innovation competence in practice. Therefore, the studies in this dissertation were designed to contribute to two main aims: (a) to explore students' and teachers' perceptions of existing curricula aimed at fostering students' innovation competence, and (b) to develop and evaluate innovation competence-supportive design principles. To achieve these goals, four research questions were formulated in the introduction to this dissertation. Both qualitative and quantitative research methods were used to answer the following research questions, which guided this dissertation:

1. To what degree do students of Built Environment education at universities of applied sciences perceive the existing learning environment as supportive for developing innovation competence, how do students perceive their own innovation competence and to what degree are their perceptions of the learning environment and of their competence related?
2. To what degree do teachers of Built Environment education at universities of applied sciences perceive their learning environments as supportive for developing innovation competence, what beliefs do they hold about innovation competence instruction and what is the interplay between these beliefs and perceptions?
3. On what design principles can innovation competence instruction be based and how can an instructional intervention be successfully implemented in practice?
4. To what extent is the innovation competence instructional intervention, based on the design principles for innovation competence-supportive teaching, effective in increasing students' innovation competence?

First, we will present the summary of main research findings. Next, an overall conclusion regarding the development of the innovation competence instruction will be presented, followed by a discussion about the usefulness of innovation competence instruction. This chapter will end with some implications for practice, limitations, and suggestions for further research.

6.2 Summary of main research findings

6.2.1 Student perceptions of existing learning environments aimed at innovation competence

Chapter two focused on students' perceptions of the learning environment with respect to innovation competence development and students' self-perceived innovation competence.

Students' perceptions of the focus and the relevance of innovation competence in their schools' curricula were also mapped, as well as the association between the learning environments and students' self-perceived innovation competence. Survey data were collected from 130 students of Built Environment programs at eight universities of applied sciences in the Netherlands. We conducted exploratory factor analyses and reliability analyses to check the psychometric quality of the survey. Both the exploratory factor analysis and reliability analysis revealed satisfactory results for both the innovation competence and learning environments constructs, as items loaded meaningfully on their respective scales.

All scores were above the mid-point of 4. Standard deviations suggested considerable differences on each aspect between students. Results showed that students perceived their levels of energy, creativity, and creative self-efficacy to be somewhat higher than their ability to solve ambiguous problems, their risk propensity, and their self-perceived leadership. Furthermore, the students on average perceived their learning environment as moderately constructivist, as all scores ranged around the midpoint of 4, with personal relevance rated the lowest, student negotiation rated the highest and uncertainty between those two. The results regarding students' perceptions of the focus on innovation competence at the school/curriculum level showed a *moderate* perceived focus on innovation competence. Regarding the question as to whether teaching students to become innovative is relevant, students reported on average a view of it as *somewhat relevant.*

Seven stepwise multiple regression analyses were conducted in order to determine the joint and unique predictive contribution of the learning environment dimensions, and the focus and relevance variables to students' total innovation competence and its individual components. These regression analyses showed that student perceptions of personal relevance were positively related to their self-perceived leadership, energy and ability to solve ambiguous problems. Perceptions of student negotiation were positively related to creativity, creative self-efficacy and overall perceived innovation competence. Perceived focus in the curriculum on innovation was positively related to self-perceived risk propensity. In all cases, the amount of explained relevance was relatively small, at about 5%. However, all associations found were statistically significant.

The results revealed that universities of applied sciences could focus more explicitly and structurally on the teaching and assessment of innovation competence. The results suggested that students perceived the existing learning environments to be less constructivist than hoped for, and revealed the need for implementing constructivist learning environment principles more explicitly. According to students' views, their teachers did not focus strongly on innovation competence instruction in their major program. Results also showed that students were positive about the relevance of being explicitly taught to be innovative by their teachers. Hence, the question arose whether teachers' views of the learning environments were different from the students' views. This question was addressed in the next study.

6.2.2 Teachers' perceptions of the existing learning environments and their beliefs about innovation competence

Based on the conclusion of the first study as presented in chapter 2, teachers, according to students' views, did not explicitly focus on innovation competence instruction in their major program. Although students' perceptions revealed an interesting picture about the perceived learning environments for stimulating innovation competence, they represent only part of the picture, as teachers' perceptions are still missing at the higher education level. Past research on learning environments in various educational domains have shown considerable differences between teachers' and students' views. Typically, in those studies students' perceptions were lower/less positive than those of teachers.

In this second study, we investigated teachers' beliefs about innovation competence relevance and their creative self-efficacy, and compared teachers' and students' perceptions of the learning environment. We also mapped teachers' perceptions of the focus on innovation competence at the school/curriculum level, as well as the association between the perceived learning environments and creative self-efficacy, school focus on innovation competence instruction and innovation competence instruction relevance. Survey data were collected from 94 Built Environment teachers, at eight universities of applied sciences in the Netherlands. Exploratory factor analysis and reliability checks were conducted to check the psychometric quality of the survey. Both the exploratory factor analysis and reliability checks revealed satisfactory results for all constructs, as items loaded meaningfully on their respective scales.

The results showed, on average, neutral perceptions for focus on innovation competence instruction. However, a wide variability in scores was found. Teachers differed greatly among each other with regard to their beliefs about the relevance of innovation competence. Only a few teachers considered teaching for innovation competence to be very relevant, while some were even negative about its relevance. This is a remarkable finding, given the relevance of innovation competence for society and economy. The results showed that teachers were confident in their creative self-efficacy. The study reported in this chapter also sought to know whether differences in perception about their learning environments existed between students and teachers. Teachers clearly scored all variables higher than students did. Statistically significant differences in perceptions were found for the learning environment variables: personal relevance, uncertainty, and student negotiation. The findings are consistent with previous studies that compared students' and teachers' perceptions.

Four stepwise multiple regression analyses were conducted in order to determine the joint and unique relationships between each of the learning environment scales, teacher-related beliefs and teachers' perceptions of focus on innovation competence at the curriculum level. These regression analyses indicated that relevance of innovation significantly and positively predicted focus on innovation competence. Focus on innovation competence at the curriculum level significantly and positively predicted uncertainty. Creative self-efficacy significantly predicted student negotiation. In all cases, the amount of explained variance ranged between 6 and 11%, which was relatively small. However, all associations found were statistically significant. Given the conclusions drawn from the needs and context analysis of the problem (chapters 2 & 3), the next step was to determine what design principles could guide the design of innovation competence-supportive learning environments in higher education.

6.2.3 Theory-based design principles for innovation competence instruction in higher education

Educational design research advocates the development of a set of design principles that are based on existing practical and theoretical principles. These principles are used to guide the design and development of learning environments and were used here to guide the design and development of an innovation competence instructional prototype. The goal of the proposed design principles is not to create a set of mandatory procedures and processes for teachers to implement, but rather to facilitate bridging the gap between educational theory and practice. This gap is related to the fact that innovation competence-supportive learning in the Built Environment engineering Educational domain is not yet the target of explicit teaching, as was revealed in the needs and context analysis conducted (Chapters 2 and 3). According to students' self-reports, the existing learning environments were limited in fostering students innovation competence in practice. Students and teachers also differed regarding the perceived presence of instruction that supports innovation competence, and most teachers did not consider innovation competence instruction relevant in their major teaching area. Therefore, a need existed for the explication and demonstration of instruction that is specifically aimed at fostering innovation competence in the Built Environment educational domain. The design principles together with their translations could serve as exemplary materials and building blocks for those seeking guidelines for developing innovation competence in their practice. Although further research is needed, this study affirms the plea that some formal instruction is necessary to enhance students' innovation competence if they are expected to contribute innovative ideas in their future work and practices. Providing professional support for students has been demonstrated to be an effective way for developing students' innovation competence.

These results of the needs and context analysis (Chapters 2 and 3) demonstrated the need for an intervention that was particularly focused on innovation competence instruction via a structured approach to innovation competence education. Based on theory and the findings of the first two studies, six design principles were formulated for the design of an innovation competence-supportive intervention. The six design principles proposed in chapter 4 portray a synthesis of conclusions drawn from several theoretical principles, practical insights and recommendations. The four-component instructional design model for complex competencies (the 4C/ID model), constructive alignment, the simplified innovation process and constructivism formed the main theoretical foundations for the six design principles. These were: a). Define holistic but measurable learning goals; b). Incorporate constructivist learning principles in the learning environment; c). Base teaching on the innovation process sequence; d). Teach sound creative techniques; e). Ensure that assessments of students' learning outcomes are simple to use, systematically aligned with the learning activities, and concise but comprehensive enough to capture relevant aspects of innovation competence; and f). Focus assessments of students' learning outcomes more on process than product.

The six design principles were arranged under three headings or aspects following constructive alignment, namely, goals, explicit teaching, and assessments. The goals described the intended learning outcomes, while explicit teaching described the teaching and learning activities as well as the teaching sequence. Lastly, assessments described the what and how of the innovation competence assessments. The goals, activities, and assessments corresponded with the three phases of the innovation process: problem discovery, creative solution idea generation and solution implementation. These design principles informed the development of the innovation competence instruction prototype, which was evaluated and tested in the study reported in the next chapter. It involved a fundamentally different approach to teaching and learning, in which learning activities intended for fostering innovation competence in students were orchestrated. Students were asked to identify innovative problems and develop innovative solutions for Built Environment domain-specific tasks. Some examples of task scenarios were making homes energy-neutral, developing mechanisms and interventions to limit flooding in flood-vulnerable regions, and identifying innovative problems and developing innovative solutions concerning traffic safety in central transportation stations. Task durations ranged from 2 to 8 weeks depending on study year and task focus.

6.2.4 The effectiveness of the innovation competence intervention

The study reported in chapter 5 was aimed at testing the effectiveness of the innovation competence intervention described in chapter 4. The innovation competence intervention came to be via several iterations at three different Built Environment engineering departments. The intervention study was part of an innovation competence instructional course (15 ECTS) and was conducted using a mixed-methods approach involving final-year students at one Netherlands university of applied sciences. Multiple data were collected. First, students were required to complete a pre- and post-test survey asking for their self-perceived innovation competence. Paired-samples t-tests were conducted to compare students' pre-test and post-test scores. Students' increases in scores for all three individual ILOs were statistically significant: students tended to agree in a relatively positive way that they had learned to raise innovative questions, devised creative solutions to the problem identified and showed that the developed solution for the problem was appropriate after the innovation competence instruction, while they more strongly disagreed that they had learned this prior to the instruction. Improvement in scores for an overarching, combined goal was also statistically significant. The magnitude of the differences in the means was very large.

Second, students' deliverables were assessed via a rubric. A pair of teachers used the 22-item matrix rubric to jointly grade 46 students' products. In total, six pairs of teachers participated in the grading process. The grading of students' final products by teachers at the end of the semester revealed that the majority of students ($N = 43$) were graded above 3 on a scale from 1 (lowest) to 5 (highest) for the combined ILOs. The teachers judged the majority of students' deliverables as satisfactory. One student's work was considered poor and the work of two students was considered excellent by their teacher.

Third, group interviews were conducted at the end of the last class session of the course with stakeholders (students and teachers). The group interview was aimed at eliciting stakeholders' opinions about the course design and content. Three groups of students were invited to participate in the group discussion. One pair of teachers from the six pairs who graded the students' deliverables were also interviewed about the innovative nature of the students' work. Students' data were organized by connecting statements to the design principles, while teachers' data were organized by connecting statements to the three learning goals. In general, the majority of the teachers who assessed students' work expressed satisfaction with students' methodical approaches to problem identification and solution generation. Teachers expressed satisfaction about students' products, especially when the client deemed the solution useful. Reflective practice was also an area teachers talked about in determining students' grades.

The interview results showed that the innovation competence intervention promoted students' understanding of the innovation process from the students' perspective. The results of different group interviews were entirely consistent and complemented the picture provided by the pre- and post- survey. Students understood the steps and procedures defined in the tasks for coming up with an innovative question or problem, the creativity and the implementation sessions. Students were confident that the procedures did not hinder their ability to think creatively or generate innovative ideas. Students also reported confidence in transferring the knowledge gained from the course to other areas of study.

Overall, analysis of both students' self-report and products assessment data showed positive effects of the six design principles for innovation competence instruction. It could be concluded that, through carefully and thoughtfully taking into account important design principles for innovation competence education, it was possible to design an adequate and useful instructional intervention for fostering students' innovation competence.

6.3 General conclusions and discussions

The core purpose of this chapter is to conclude the current study by highlighting the main research findings and their implications for both practice and science. First, the study's findings regarding the research aims are outlined, including their implications. Second, the chapter draws conclusions concerning the main contributions of the current study to the body of knowledge. The third section highlights the limitations of the study, and then the chapter ends with suggestions for future research.

6.3.1 The first research aim: to explore students' and teachers' perceptions of the existing curricula aimed at fostering students' innovation competence

Related to the first research aim, as pursued in research questions 1 & 2, four general conclusions are drawn from the current study that could be useful for Built Environment teachers, the Netherlands Association of Universities of Applied Sciences and innovation competence research in general.

The first general conclusion generated from this study is that both students and teachers considered the existing learning environment limited/moderately constructivist and therefore only partly suitable for developing students' innovation competence. This finding is in line with other studies (Beghetto & Kaufman, 2014; Choo, 2018; Edwards-Schacter et al., 2015; Hero, 2017; Kasule et al., 2015). We attribute this finding mainly to lack of proper facilitation of constructivist teaching in terms of know-how, time and resources (Beghetto & Kaufman, 2014; Choo, 2018; Hero, 2017; Kasule et al., 2015; Nielsen, 2015). It is important that teachers are provided with the necessary support and guidance, as teaching innovation competence is complex and requires hard work. Our findings demonstrate the need for providing teachers with supportive mechanisms to help them develop the underlying skills necessary to support the development of students' innovation competence in their classroom practices. In this light, interventions are urgently needed to support teachers (Kasule et al., 2015). It was vividly stated in the curriculum statements of Built Environment engineering Educational domain that innovation competence is an ultimate goal that all students must attain. Yet, results showed, according to students' views, that an innovation competence instruction focus is still relatively limited in their learning environments. Teachers did not always consider innovation competence relevant, nor could they confirm an explicit focus on innovation competence in their classroom practices. These findings show that education policy and curriculum statements alone are not sufficient mechanisms to realize innovation competence-supportive learning environments in higher education and that additional strategies are necessary. Creating professional training programs for teachers and providing supportive resources may assist teachers in incorporating innovation competence instruction in higher education classroom practice. Without professional guidance and supportive resources, teachers may get frustrated, demotivated and lack the necessary know-how about innovation competence instruction. Past studies where teachers received some professional support revealed that teachers valued innovation competence more and that such teaching was effective in developing students' innovation competence (Abd Hamid, 2006; Gul et al., 2014; Hsu, 2007; Ijaiya et al., 2010; Phillips & Duke, 2001; Profetto-McGrath et al., 2004; G. Scott et al., 2004; Sellappah et al., 1998; R. E. West et al., 2012; Wink, 1993; Wright et al., 2013). The results of this study are very encouraging, as several positive changes were noted in the educators' classroom teaching practices post-intervention.

The second general conclusion drawn from the study is that students were more negative than teachers about all aspects of the learning environments as related to innovation competence instruction. This finding is consistent with previous research that studied teacher and student perceptions of their learning environments (den Brok et al., 2006; Fraser, 2007; Wahyudi & Treagust, 2003; Wubbels et al., 2006). One explanation is the role of the teacher in the learning environments. Teachers have an active role, rather than an observer role, in the learning environments (den Brok et al., 2006; Fraser, 2007; Vennix et al., 2017; Wahyudi & Treagust, 2003; Wubbels et al., 2006). According to Chan and Yuen (2014) and Hondzel (2013), when teachers were asked if they support creativity in their practice, they often reported a high-level focus on the development of students' creativity. However, studies that have observed teachers' actual teaching behaviours in practice with respect to fostering creativity have often reported fewer positive results (Alkhars, 2013; Lev-Zamir & Leikin, 2013; Meyer & Lederman, 2013; Shaheen, 2011). Teachers are the major actors in creating the learning environments. For this reason, they may be more inclined to report positive perceptions of their own learning environment. Another explanation is related to the level of innovation competence instruction explicitness. Explicit teaching is teaching that is focused on producing specific learning outcomes. Topics and contents are broken down into small parts and taught individually. It involves explanation, demonstration and practice. Explicit teaching strives to direct students' attention toward specific learning goals in a structured environment. When innovation competence instruction is made explicit, students have acknowledged such teaching and reported positive learning effects (Wright et al., 2013). Therefore, it is important to educate teachers about the need to make innovation competence instruction explicit by creating a space in the curriculum especially dedicated to developing students' innovation competence. Otherwise, the lack of explicitness is more likely to lead to a lack of focus on innovation competence instruction and recognition by students, as was argued by Wright et al. (2013). It is also important to review both the perceptions of students and teachers, so that teachers get a realistic picture and do not just rely on their own image of the situation.

The third general conclusion drawn from the study is that students rated their own innovation competence reasonably high. This result is consistent with the work of Chell and Athayde (2009), where similar results were found. As previously mentioned, the development of innovations requires the accomplishment of a set of innovation tasks (Kanter, 1988), including the exploration of opportunities to innovate as well as the generation, promotion, and realization of innovative ideas. The results showed that students perceived themselves on average to be sufficiently competent in accomplishing innovation-related tasks; higher scores were reported for creativity, leadership, energy and creative self-efficacy, but lower scores for risk propensity and ability to solve ambiguous problems. According to Chell and Athayde (2009), high scores on the innovation competence scales should represent students' intentions to become future innovators. However, only measuring self-perceptions is not sufficient; performance should also be visible, in experts' or teachers' judgments of course products.

The fourth and final general conclusion is that teachers considered innovation competence only moderately important and reported a limited presence of innovation competence-supportive teaching. Surprisingly, the majority of the teachers had a neutral opinion. Just 13% perceived teaching innovation competence as somewhat relevant, while 14% of the teachers considered teaching innovation competence very irrelevant. The relative newness of the innovation competence instruction topic may be an explanation for this finding. Teachers may not have the know-how to integrate innovation competence into their teaching routine, as limited teaching guidelines exist for this competence. This could explain why studies that observed teachers' practice have rarely found traces of teaching aimed at innovation competence (Savasci & Berlin, 2012). Another explanation is related to the complexity of innovation competence: teachers may believe students are not capable of learning to become innovative, as they see that students still struggle to reproduce the knowledge passed along to them by their teacher. Studies have shown that the beliefs that teachers have about students affect their teaching practice (Bassett, 2004; Beck et al., 2000; Davis & Rimm, 1998; Saylan et al., 2016; Sternberg & Williams, 1996). Teachers' beliefs are structured sets of principles derived from prior experiences, school practices, and a teacher's individual personality (Borg, 2003). According to Shavelson and Stern (1981), what teachers do in the classroom is governed by what they believe, and these beliefs often serve as a filter through which instructional judgments and decisions are made.

Together, these findings are supported by earlier studies on other types of competence and learning environments (Anagun & Anilan, 2013; den Brok et al., 2006; Fraser, 2007; Saylan et al., 2016; Vennix et al., 2017; Wahyudi & Treagust, 2003; Wubbels et al., 2006). The overall conclusion drawn based on the first research aim is that explicit attention should be paid to innovation competence education, but also that teachers are not yet convinced of its importance. Students think they are innovation competent, but the question is, what happens when their innovation competence is actually tested.

6.3.2 The second research aim: to develop and evaluate innovation competence-supportive design principles

The second research aim was pursued by the development and evaluation of the innovation competence-supportive design principles. As mentioned earlier, one output of educational design research is offering educational solutions to complex educational problems. However, from a scientific perspective, the main output of educational design research approach is to contribute to theory development, in this case, theory about innovation competence learning in higher education, through the design of instruction that can survive the challenges of everyday practice (Shavelson, 2003). Therefore, research involving an educational design research approach is expected to yield intimate knowledge about the theoretical and design ideas involved in the intervention (Joseph, 2004). According to McKenney et al. (2006), knowledge about how to build and implement educational solutions in any setting takes the form of design principles. Design principles are not intended as recipes for successful designs but are rather theory-based conjectures, which underpin design, and are refuted, validated or refined based on the research findings (McKenney & Reeves, 2019).

This dissertation research is educational design research in which six design principles were generated for innovation competence instruction in the Built Environment engineering domain. As indicated above, the six design principles were theoretically based and were validated by empirical evidence; together they offer generalized guidance for designing and implementing innovation competence-supportive teaching and learning in the Built Environment engineering context in higher education.

Findings regarding the second research aim showed that all principles appeared to be implementable; all principles also turned out to be important, in that not one was missing in the interviews. No new principles emerged during implementation or evaluation. In this study, the design principles suggesting basing teaching on the innovation process sequence and teaching sound creative techniques were the principles most valued by students, and in their view contributed the most to developing students' innovation competence. These principles were also the most visible element for students in the innovation competence instruction learning environment.

The above findings regarding this dissertation study's aims suggested that innovation competence is attainable via explicit instruction and that higher education institutions have an important role in developing innovative individuals. To develop students' innovation competence in any educational domain, new and valid instructional tools are required. Teachers also need to have the know-how to design and implement innovative supportive instruction. However, teaching complex innovation competence can be very challenging for teachers. Without instructional aids, fostering students' innovation competence may require much more effort from the teacher. In the current study, the researcher's role was an active one in the design phase and implementation phase, as the teacher experienced difficulties in the design and execution of innovation competence-supportive instruction. Our observations based on informal observation during the implementation studies were that, when teachers were asked to independently design innovation competence-supportive instruction for their students, they tended to experience a) difficulties in designing activating tasks for students, b) difficulties in allotting realistic time frames for implementing all teaching and learning activities, and c) difficulties in scaffolding innovation competence instruction and connecting with relevant theories. Meeting these conditions is necessary for the effectiveness of innovation competence instruction in any educational context (Hung, 2006).

The studies making up this dissertation succeeded in creating instruction for innovation competence-supportive learning, as well as theoretical perspectives for approaching the problematic discussion of complex competence and innovation competence research by creating a lens by which innovation competence-supportive education can be explored in existing practices regardless of educational domain. This dissertation study, according to the self-evaluation reports of participants, showed that innovation competence can be learned by students, assessed by teachers and supported in higher educational environments. For example, with the self-evaluation assessment tools, students were able to describe the different learning situations during the innovation competence instruction course, reflect on their learning experiences and describe their expertise for innovating. These findings are consistent with the results of previous studies. For instance, the study by Chang et al. (2007) demonstrated the usefulness of self-evaluation in the assessment of students' learning. Keinänen and Butter (2018) used self-assessment to measure students' innovation competence. The study by Butter (2013) showed that innovation competence self-assessment tools supported the self-reflection and choices of students.

The next sections discuss these aspects in terms of the scientific, methodological and practical implications, followed by directions for future research.

6.4 Scientific limitations and suggestions for future research

This dissertation has shown that the innovation competence intervention as described is effective for improving students' innovation competence in the Built Environment educational domain. Nevertheless, along with answers, this thesis holds some implications for future investigations of innovation competence-supportive instruction and learning environments. First, innovation competence may be seen as a generic competence and as such, is not necessarily domain-specific. Viewed from that perspective, the instructional materials generated from this dissertation study can be translated to other educational domains. However, because this intervention was conducted in one educational domain and at one university of applied sciences, implementing the intervention in other educational domains and other universities of applied sciences will provide useful knowledge about the intervention principles' wide implementation and validity. Also, the research used different surveys and instruments to study the innovation competence learning environment. Future studies could further improve the surveys and instruments used in this thesis in other educational domains, for example by strengthening the internal consistency and reliabilities of certain measures, especially measures like focus on innovation competence and risk propensity. Moreover, one of the limitations of this study is that it was conducted in only one educational domain. Future studies should cover other educational domains (e.g., academic universities, vocational colleges, and lower educational institutions). These studies will add to the weight of the evidence regarding the description of the actual picture concerning the state of affairs concerning innovation competence education in other curricula and help determine whether those pictures vary in any significant way across domains or across engineering disciplines.

Second, studying and devising instructional principles for innovation competence in a higher education domain was not only complex, but required hard work on the part of the researcher. Nevertheless, this thesis represents a first but dedicated attempt to studying innovation competence-supportive learning environments at universities of applied sciences, and the results showed that innovation competence-supportive learning environments in this educational domain are still somewhat limited. More studies should be carried out to deepen the insights provided by the thesis. For instance, the findings regarding innovation competence relevance were studied using a survey. Beliefs about the relevance of innovation competence should also be investigated qualitatively to achieve an in-depth understanding about the relevance a teacher assigns to innovation competence. Other research areas that could be explored qualitatively to achieve deep understanding are understanding the relationship between beliefs and perceptions, and perceptions and outcomes. Past studies where teachers received some professional support revealed that teachers' beliefs and value for innovation competence changed as a consequence (Abd Hamid, 2006; R. E. West et al., 2012; Wright et al., 2013).

Third, the study focused on only on the perceptions of teachers and students. Future studies could involve other educational organization employees (e.g., deans, team leaders, curriculum and committee chairs); and other organizational levels, such as upper, middle, and lower management and non-management salaried and hourly paid employees. This is necessary in order to expand the scope of the sample and to identify other key factors influencing innovation competence education in other domains. This thesis was also strongly focused on how to improve students' innovation competence; it did not consider how to support or train teachers to improve students' innovation competence nor teachers' own innovation competence. Further studies may extend the outputs of this thesis by testing whether teachers' own innovation competence can be improved, and whether such training can help teachers to create their own innovation competence-supportive courses.

Finally, the thesis was characterized by the researcher's actions and active involvement during most research phases. Future studies may strive to investigate the effective balance between the researcher's actions and active involvement in providing structure and scaffolding, and the autonomy needed by teachers themselves to promote innovation competence. Quasi-experimental studies with control and experimental groups could help in determining the optimal levels of involvement. Complementary qualitative methods could be used to describe the level of involvement found to be most effective and to examine how participants perceived, used, experienced, and benefited from this involvement.

6.5 Practical implications

Our study contributes several starting points for fostering the development of students' innovation competence in higher education organizations such as universities of applied sciences. First, concerning how to structure innovation competence education, the study deconstructed innovation competence into six components that characterised an innovator and three main phases innovators follow to mature an innovation. This deconstruction was necessary and brought understanding and direction as to how to phase and structure innovation competence instruction in Built Environment education. To foster innovation competence, educators must know what characterizes innovative individuals and what process they follow to achieve mature innovations (Amabile, 1996; Baron, 2004; Butter & Van Beest, 2017; Chell & Athayde, 2009; Fisher et al., 2011; Hamza & Griffith, 2006; R. E. West et al., 2012; Wright et al., 2013; Zenobia, 2013). The study explicated six characteristics of innovators – *creativity, leadership, creative self-efficacy, energy, risk propensity and solving ambiguous problems* (Chell & Athayde, 2009; Hunter et al., 1977; Tierney & Farmer, 2002) and three interrelated process phases (or subtasks) of *innovative problem discovery* (Cross, 2002; Dym, 1994; Lumsdaine et al., 1999; Martindale, 1999), *creative solution idea generation* (Amabile, 1996; Chan & Yuen, 2014; Fisher et al., 2011) and *solution implementation* (Cross, 2002; Fisher et al., 2011; Lumsdaine & Binks, 2006). Therefore, our deconstruction of innovation competence can be seen and used as a format for the design and alignments of innovation competence learning. It provides clues and structure for tasks design; teaching and learning activities design; assessment design; and alignment of teaching and learning activities with assessments.

Second, the study generated handy surveys and tools to determine the extent to which the learning environment is innovation competence-supportive, describes students' perceptions of their own innovation competence and teachers' diverse innovation competence-related beliefs. To improve innovation competence via supportive teaching, an understanding of teachers' and students' perceptions and beliefs is necessary. By using the surveys, important clues about innovation competence education/instruction can be provided to teachers, educational organizations and policy makers. The survey can be used to detect and direct teaching interest towards innovation competence by explicating and identifying the problem areas. Finally, the use of the survey can facilitate students' learning and understanding of innovation competence. It may serve as a lens to identify innovative students and their contributions to innovation development, to encourage an innovation competence mindset in students, and as an instrument to identify educational organizational loopholes in the curricula related to innovation competence instruction.

Third, this study yielded concrete examples of teaching materials and tools in the form of rubrics for assessing innovation competence, and so forth. For instance, teachers can use the assessment rubrics to measure the development of students' innovation competence throughout the degree programmes as well as to measure the effectiveness of their own teaching interventions. The assessment rubrics can also help students to actively monitor and regulate their own learning by reflecting on the individual items in the rubrics. In this way, students will develop a better understanding of their own innovation competence levels, which supports students' metacognitive skills. Results revealed that despite teachers' awareness of the significance of innovation for society, they initially did not explicitly support their students' innovation competence. Providing teachers with teaching tools will not only encourage them, but may also help them to better focus their innovation competence instruction in their practice.

Fourth, this dissertation study yielded six useful design criteria for developing innovation competence supportive- learning environments in the context of higher education. These principles can be used as a checklist or substantiation in practice. These principles provide a means for fostering students' innovation competence and could serve as a guideline or checklist for teachers to evaluate or reflect on their teaching materials and actions in practice. For instance, the principles stressed the relevance of incorporating constructivist principles in the learning environments. Teachers could use this principle to check the opportunities they provide for students to engage with real-world problems in the field of study in order to have a rich and meaningful learning experience (Fasko, 2001, p. 322). Teachers could also use the principles to direct their teaching towards how to explore, collect, analyse, and use data to spark innovation (Dyer et al., 2009; Honebein, 1996). Accordingly, the design principles along with their translations are readily available for teachers' use to create innovation competence-supportive instruction in their practice, as well as assessments of their students' learning. Because the principles are in fact a definition of the conditions and criteria for an innovative competence-supportive learning environment, they explicate the proficiencies teachers must develop in order to successfully support innovation competence in their students. Their translations can serve as worked examples and inspirational materials for teachers in their efforts to create innovation competence-supportive learning environments for students. As such, the principles can also be used as important insights for developing teachers' own innovation competence, whether via self-study or professional training.

Consequently, insights from this thesis can be used to develop professional training for teachers, as well as teacher education on the subject of innovation competence instruction. For instance, specific modules on innovation competence can be generated focusing on the what, how, and why aspects of each design principle.

Finally, via this dissertation, we know better what is needed by teachers and the difficulties involved in fostering students' innovation competence within existing curricula, and that training, sufficient time, motivation and other support are needed to allow teachers to do this themselves.

6.6 Closing remarks

This dissertation suggests that innovation competence instruction research is still in its elementary stage, but that the results of creating an innovation competence-supportive environment are very promising. There is much to feel encouraged about. For example, multiple measures of the effectiveness of the innovation competence instruction revealed the instruction's effectiveness in fostering students' innovation competence. Furthermore, assessment models integrating diverse teaching and learning activities appeared useful in capturing students' innovative learning products. Finally, several future directions for research have been identified.

In conclusion, it appears that innovation competence, following the conclusions drawn from this dissertation research, can be influenced by instruction. The findings from this study suggested that students' innovation competence instruction occurs through explicitly aligned design of activities, assessment and reflection; that this innovation competence-supportive learning environment influenced actual students' innovation competence, and that classroom enactment (in particular, a better structured, balanced and more learner-centred constructivist approach to teaching) positively influenced students' innovation competence learning. This dissertation revealed that students have the potential to be innovative, and that educators can assume their role by acknowledging students' innovation potential by creating a teaching and learning environment that fosters and encourages innovation competence.

It is our sincere hope that this line of research continues with full momentum across domains, in collaboration with researchers and educators from different fields, to jointly investigate how innovation competence can be fostered via explicit teaching, so that all students and teachers can benefit from explicit innovation competence instruction.

References

Abd Hamid, N. H. (2006). *Analysis of changes in teachers concerning constructivist perception, philosophies, and practices resulting from the year-long Iowa Chautauqua Professional Development Project* (Unpublished doctoral dissertation). University of Iowa, Iowa City.

Adams, J. W. (2013*). A case study: Using lesson study to understand factors that affect teaching creative and critical thinking in elementary classroom* (Doctoral dissertation). Available from ProQuest Dissertations and Theses database. (UMI No. 1356692081).

Aish, D. (2014). *Teachers' beliefs about creativity in the elementary classroom* (Doctoral dissertation) Available from ProQuest Dissertations and Thesis database. (UMI No. 1566193678).

Ajzen, I. (1991). The theory of planned behavior. *Organizational Behavior and Human Decision Processes*, *50*(2), 179–211.

Ajzen, I. (2002). Perceived behavioral control, self-efficacy, locus of control, and the theory of planned behavior. *Journal of Applied Social Psychology*, *32*(4), 665–683. https://doi.org/10.1111/j.1559-1816.2002.tb00236.x.

Aldridge, J. M., & Fraser, B. J. (2011). Effects and determinants of outcomes-focused learning environments. *Curriculum and Teaching*, *26(1),* 5–31.

Aldridge, J. M., Fraser, B. J., Taylor, P. C., & Chen, C. C. (2000). Constructivist learning environments in a cross-national study in Taiwan and Australia. *International Journal of Science Education*, *22,* 37–55.

Alkhars, D. A. M. A. (2013*). Creativity in English language teaching in Kuwait: A TESOL study* (Doctoral dissertation). Available from ProQuest Dissertations and Theses database. (UMI No. 1654747399).

Al-Nouh, N. A., Abdul-Kareem, M. M., & Taqi, H. A. (2014). Primary school EFL teachers' attitudes towards creativity and their perceptions of practice. *English Language Teaching*, *7*(9), 74–90. http://dx.doi.org/10.5539/elt.v7n9p74.

Alsop, R. J. (2003). *The Wall Street Journal: Guide to the top business schools.* Simon & Schuster.

Amabile, T. M. (1988). A model of creativity and innovation in organizations. *Research in Organizational Behavior*, *10,* 123–167.

Amabile, T. M. (1996). *Creativity in context*. Westview.

Amabile, T. M., Conti, R., Coon, H., Lazenby, J., & Herron, M. (1996). Assessing the work environment for creativity. *Academy of Management Journal*, *39*(5), 1154–1184. doi:10.2307/256995.

Amabile, T., & Pratt, M. G. (2016). The dynamic componential model of creativity and innovation in organizations: Making progress, making meaning. *Research in Organizational Behavior, 36*, 157–183.

Anagun, S. S., & Anilan, H. (2013). Development and validation of a modified Turkish version of theTeacher Constructivist Learning Environment Survey (TCLES). *Learning Environments Research, 16*, 169–182.

Andiliou, A., & Murphy, K. P. (2010). Examining variations among researchers' and teachers'conceptualizations of creativity: A review and synthesis of contemporary research. *Educational Research Review*, *5*(3), 201–219. http://dx.doi.org/10.1016/j.edurev.2010.07.003.

Antonietti, A., Colombo, B., & Pizzingrilli, P. (2011). The WCR model of creativity: From concept to application. *The Open Education Journal, 4,* 80–89.

Assink, M. (2006). Inhibitors of disruptive innovation capability: A conceptual model. *European Journal of Innovation Management, 9*(2), 215–233.

Avvisati, F., Jacotin, G., & Vincent-Lancrin, S. (2013). Educating higher education students for innovative economies: What international data tell us. *Tuning Journal for Higher Education*, *1*, 223–240.

Badcock, P. B., Pattison, P. E., & Harris, K. (2010). Developing generic skills through university study: A study of arts, science and engineering in Australia. *Higher Education*, *60*(4), 441–458.

Baillie, C., & Walker, P. (1998). Fostering creative thinking in student engineers. *European Journal of Engineering Education, 23*, 35–44.

Bandura, A. (1986). *Social foundations of thought and action: A social cognitive theory*. Prentice Hall.

Bandura, A. (1997). *Self-efficacy: The exercise of control.* Macmillan.

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

Baron, R. (2004). The cognitive perspective: a valuable tool for answering entrepreneurship's basic "why" question. *Journal of Business Venturing*, *19*(2004), 221–239.

Barrie, S. C. (2007). A conceptual framework for the teaching and learning of generic graduate attributes. *Studies in Higher Education, 32(4)*, 439–458.

Basadur, M., Graen, G. B., & Green, S. G. (1982). Training in creative problem solving: Effects on ideation and problem finding and solving in an industrial research organization. *Organizational Behavior and Human Performance*, *30*, 41–70.

Bassett, P. (2004). Creativity in schools. *Independent Schools*, *26*(2), 7–8.

Bath, D., Smith, C., Stein, S., & Swann, R. (2004). Beyond mapping and embedding graduate attributes: Bringing together quality assurance and action learning to create a validated and living curriculum. *Higher Education Research & Development*, *23*(3), 313–328.

Beck, J., Czerniak, C. M., & Lumpe, A. T. (2000). An exploratory study of teachers' beliefs regarding the implementation of constructivism in their classroom. *Journal of Science Teacher Education, 11,* 323–343.

Beghetto, R. (2010). Creativity in the classroom. In J. C. Kaufman & R. J. Sternberg (Eds.) The Cambridge handbook of creativity (pp. 447–459). Cambridge University Press.

Beghetto, R. A. (2005). Does assessment kill student creativity? *The Educational Forum, 69*(2), 254–263.

Beghetto, R. A., & Kaufman, J. C. (2013). Fundamentals of creativity. *Educational Leadership, 70,* 10–15.

Beghetto, R. A., & Kaufman, J. C. (2014). Classroom contexts for creativity. *High Ability Studies, 25*(1), 53–69.

Beghetto, R. A., Kaufman, J. C., & Baxter, J. (2011). Answering the unexpected questions: exploring the relationship between students' creative self-efficacy and teacher ratings of creativity. *Psychology of Aesthetics, Creativity, and the Arts, 5,* 342–349. http://dx.doi.org/10.1037/a0022834.

Beghetto, R. A., & Plucker, J. A. (2006). The relationship among schooling, learning, and creativity: "All roads lead to creativity" or "You can't get there from here?". In J. C. Kaufman & J. Baer (Eds.), *Creativity and reason in cognitive development* (pp. 316–322). Cambridge University Press.

Bel, R. (2010). Leadership and innovation: Learning from the best. *Global Business and Organizational Excellence, 29*(2), 47–60.

Bell, L., & Aldridge, J. (2014). *Student voice, teacher action research and classroom research* (Advances in learning environments research series). Sense Publishers.

Belski, I. (2009). Teaching thinking and problem solving at university: A course on TRIZ. *Creativity and Innovation Management, 18*(2), 101–108.

Bereczki, E. O., & Kárpáti, A. (2017). Teachers' beliefs about creativity and its nurture: A systematic review of the recent research literature, *Educational Research Review, 23,* 25–56. doi: 10.1016/j.edurev.2017.10.003.

Berliner, D. C. (2005). The place of process-product research in developing the agenda for research on teacher thinking. In P. M. Denicolo & M. Kompf (Eds.), *Teacher thinking and professional action* (pp. 3–16). Routledge.

Bialik, M., & Fadel, C. (2015). *Skills for the 21st century: What should students learn?* Center for Curriculum Redesign. Retrieved from https:// curriculumredesign.org/wp-content/uploads/CCR-Skills_FINAL_June2015.pdf.

Biggs. J., & Tang. C. (2011). *Teaching for quality learning at university – What the student does* (4th ed.). SRHE/Open University Press.

R

Bikfalvi, A., Jussila, J., Suominen, A., Kantola, J., & Vanharanta, H. (2010). How to boost innovation culture and innovators? In A. Gunasekaran & M. Sanduh (Eds.), *Handbook of business and information management systems* (pp. 359–381). World Scientific.

Binkley, M., Erstad, O., Herman, J., Raizen, S., Ripley, M., Miller-Ricci, M., & Rumble, M. (2012). Defining twenty-first century skills. In B. McGaw & E. Care (Eds.), *Assessment and teaching of 21st century skills* (pp 17–66). Springer.

Bjornali, E., & Støren, L. (2012). Examining competence factors that encourage innovative behavior by European higher education graduate professionals. *Journal of Small Business and Enterprise Development, 19*(3), 402–423.

Black, P., Harrison, C., Lee. C, Marshall, B., & William, D. (2003). *Assessment for learning: Putting it into practice.* Open University Press.

Bohlinger, S. (2012). Qualification frameworks and learning outcomes: challenges for Europe's lifelong learning area. *Journal of Education and Works, 25(*3), 279–297.

Bologna Process. (2015). *Yerevan communiqué for the European higher education area.* European Higher Education Area Ministerial Conference, Yerevan, 15 May 2015. Retrieved October 10, 2015, from http://bologna-yerevan2015.ehea.info/files/YerevanCommuniqueFinal.pdf.

Borg, S. (2003). Teacher cognition in language teaching: a review of research on what language teachers think, know, believe, and do. *Language Teaching 36*(2), 81–109.

Brookes, S., Moseley, A., & Underwood, S. (2012). *Contextual games: Pervasive learning activities in enterprise education (a case study).* In ISBuilt Environment Conference Proceedings: 2012 Dublin Conference (CD-ROM), Dublin, Ireland.

Burgess, L., & Addison, N. (2007). Conditions for learning: Partnerships for engaging secondary pupils with contemporary art. *JADE, 26*(2)*,* 185–198.

Butter, R. (2013, November). *Online self-assessment as a quality assurance tool in higher professional education.* Paper presented at the Consortium on Applied Research and Professional Education, 4-6 November, 2013, at Manchester Metropolitan University, Manchester, England.

Butter, R., & van Beest, W. (2017). *Psychometric validation of a tool for innovation competencies development and assessment*. Available at: blog/2017/3/27/psychometricvalidation-of-a-tool-for-innovation-competencies-development.

Campbell, W. K., Goodie, A. S., & Foster, J. D. (2004). Narcissism, confidence, and risk attitude. *Journal of Behavioral Decision Making, 17,* 297–311.

Castillo, J., Caruna, C., & Wainwright, D. (2011). The changing concept of competence and categorisation of learning outcomes in Europe: Implications for the design of higher education radiography curricula at the European level. *Radiography, 17,* 230– 234.

Chan, S., & Yuen, M. (2014). Personal and environmental factors affecting teachers' creativity-fostering practices in Hong Kong. *Thinking Skills and Creativity, 12*, 69–77.

Chang, Y., Kantola, J., & Vanharanta, H. (2007). A study of creative tension of engineering students in Korea. *Human Factors and Ergonomics in Manufacturing & Service Industries, 17*(6), 511–520.

Chell, E., & Athayde, R. (2009). *The identification and measurement of innovative characteristics of young people*. NESTA.

Cheng, V. M. (2010). Tensions and dilemmas of teachers in creativity reform in a Chinese context. *Thinking Skills and Creativity, 5*(3), 120–137.

Choo, S. (2018). Approaching twenty-first century education from a cosmopolitan perspective, *Journal of Curriculum Studies, 50*(2), 162–181, DOI: 10.1080/00220272.2017.1313316.

Choy, S. C., & Cheah, P. K. (2009). Teacher perceptions of critical thinking among students and its influence on higher education. *International Journal of Teaching and Learning in Higher Education, 20*(2), 198–206. Retrieved from http://www.isetl.org/ijtlhe/pdf/IJTLHE336.pdf.

Chung, C. (2011). Changing engineering curriculum in the globalizing world. *New Horizons in Education, 59*, 59–70.

Cobo, C. (2013). Skills for innovation: Envisioning an education that prepares for the changing world. *Curriculum Journal, 24*(1), 67–85.

Cohen, J. (1988). *Statistical power analysis for the behavioral sciences*. Erlbaum.

Copple, C., & Bredekamp, S. (2009). *Developmentally appropriate practice in early childhood programs*. National Association for the Education of Young Children.

Cropley, A. J. (2001). *Creativity in education and learning: A guide for teachers and educators*. Kogan Page.

Costa, P. T., Jr., & McCrae, R. R. (1992). Four ways five factors are basic. *Personality and Individual Differences, 135*, 653–665.

Craft, A. (2005). *Creativity in schools: tensions and dilemmas*. Routledge.

Craft, A. (2011). *Creativity and education futures: Learning in a digital age*. Trentham Books.

Cloud-Hanson, K.A., Kuehner, J.N., Tong, L., Miller, S., & Handelsman, J. (2008). Money, sex and drugs: A case study to teach the genetics of antibiotic resistance. *CBE Life Sciences Education, 7*, 302-309.

Crawley, E., Malmquist, J., Ostlund, S., & Brodeur, D. (2007). *Rethinking engineering education: The CDIO approach*. Springer.

Cross, N. (2002). Creative cognition in design: Processes of exceptional designers. In T. T. Hewitt & T. Kavanaugh (Eds.), *Creativity and cognition* (pp. 14–19). Loughborough University.

Cuenca, L., Fernández-Diego, M., Gordo, M., Ruiz, L., Alemany, M. M. E., & Ortiz, A. (2015). Measuring competencies in higher education. The case of innovation competence. In M. Peris-Ortiz & J. M. Merigó Lindahl (Eds.), *Sustainable learning in higher education: Developing competencies for the global marketplace* (pp. 131–142). Springer.

Dababneh, K., Ihmeideh, F. M., & Al-Omari, A. A. (2010). Promoting kindergarten children's creativity in the classroom environment in Jordan. *Early Child Development and Care, 180*(9), 1165–1184. http://dx.doi.org/10.1080/03004430902872950.

Dai, D. Y., & Sternberg, R. J. (2004). *Motivation, emotion and cognition: Integrative perspective on intellectual functioning and development.* Erlbaum.

Dalke, A. F., Cassidy, K., Grobstein, P., & Blank, D. (2007). Emergent pedagogy: Learning to enjoy the uncontrollable—and make it productive. *Journal of Educational Change*, *8*(2), 111–130.

Daly, S. R., Mosyjowski, E., & Seifert, C. M. (2014). Teaching creativity in engineering courses. *Journal of Engineering Education, 103*, 417–449.

Daly, S. R., & Seifert, C. M. (2019). Teaching creative process across disciplines. *Journal of Creative Behavior*, *53*(1), 5–17. DOI: 10.1002/jocb.158

Das, S. (2012). On two metaphors for pedagogy and creativity in the digital era: Liquid and solid learning. *Innovations in Education and Teaching International*, *49*(2),183–193. http://dx.doi.org/10.1080/14703297.2012.677594.

Davies, D., Jindal-Snape, D., Collier, C., Digby, R., Hay, P., & Howe, A. (2013). Creative learning environments in education - A systematic literature review. *Thinking Skills and Creativity*, *8*, 80–91. http://dx.doi.org/10.1016/j.tsc.2012.07.004.

Davis, G., & Rimm, S. (1998). *Education of the gifted and talented.* Allyn and Bacon.

De Bono, E. (1970). *Lateral thinking: A textbook of creativity.* Ward Lock Educational.

DeHaan, R. L. (2009). Teaching creativity and inventive problem solving in science. *CBE Life Sciences Education*, *8*, 172–181. doi:10.1187/cbe.08-12-0081.

den Brok, P., Bergen, T., & Brekelmans, M. (2006). Convergence and divergence between teachers' and students' perceptions of instructional behavior in Dutch secondary education. In D. L. Fisher & M. S. Khine (Eds.), *Contemporary approaches to research on learning environments: World views* (pp. 125–160). World Scientific.

Dewulf, S., & Baillie, C. (1999) *Case: how to foster creativity.* DfEE.

Dezutter, S. (2011). Professional improvisation and teacher education. In R. Sawyer (Ed.), *Structure and improvisation in creative teaching* (pp. 27–50). Cambridge University Press. doi:10.1017/CBO9780511997105.003.

Diakidoy, N. A., & Kanari, E. (1999) Student teachers' beliefs about creativity. *British Educational Research Journal*, *25*(2), 225–244.

Dillon, P., Craft, A., Best, P., Rigby, A., & Simms, K. (2007). *Turning peases west inside out: Flexible educational environments for developing possibilities and pedagogies.* Creative Partnerships Durham.

Dodgson, M., Gann, D. M., & Slater, A. J. (2002). The intensification of innovation. *International Journal of Innovation Management, 6*(1), 1–31.

Doolittle, J. H. (1995). Using riddles and interactive computer games to teach problem-solving skills. *Teaching of Psychology, 22*(1), 33-36. doi:10.1207/s15328023top2201_10.

Dorman, J., & Fraser, B. J. (2009). Psychosocial environment and affective outcomes in technology-rich classrooms - Testing a causal model. *Social Psychology of Education, 12*(1), 77–99.

Driscoll, M. P. (2005). *Psychology of learning for instruction* (3rd ed.). Allyn and Bacon.

Duderstadt, J. J. (2008). *Engineering for a changing world: A roadmap to the future of engineering practice, research, and education.* The Millennium Project, The University of Michigan.

Dyer, J. H., Gregersen, H. B., & Christensen, C. M. (2009). The innovator's DNA. *Harvard Business Review, 87*(12), 61–67.

Dym, C. L. (1994). Teaching design to freshmen: Style and content. *Journal of Engineering Education, 83*(4), 303–310.

Edelson, D. C. (2002). Design research: What we learn when we engage in design. *The Journal of the Learning Sciences, 11*(1), 105-121.

Ebgu, C. O. (2004). Managing knowledge and intellectual capital for improved organizational innovations in the construction industry: an examination of critical success factors. *Construction and Architectural Management, 11*(5), 301–315.

Edwards, M, Sánchez-Ruiz, L. M., Tovar-Caro, E., & Ballester-Sarrias, E. (2009). Engineering students' perceptions of innovation and entrepreneurship competences. In *Proceedings of the 39th IEEE Frontiers in Education Conference* (pp. 638–642). IEEE Press.

Edwards-Schacter, M., García-Granero, A., Sánchez-Barrioluengo, M., Quesada-Pineda, H., & Amara, N. (2015). Disentangling competence: Interrelationships on creativity, innovation and entrepreneurship. *Thinking Skills and Creativity, 16*, 27–39.

Ericsson, K. A. (2006). The influence of experience and deliberate practice on the development of superior expert performance. In K. A. Ericsson, N. Charness, P. Feltovich, & R. R. Hoffman (Eds.), *The Cambridge handbook of expertise and expert performance* (pp. 685–706). Cambridge University Press.

Ericsson, K. A., Charness, N., Feltovich, P. J., & Hoffman, R. R. (Eds.). (2006). *The Cambridge handbook of expertise and expert performance.* Cambridge University Press.

Ernest, P. (1995). The one and the many. In L. Steffe & J. Gale (Eds.), *Constructivism in education* (pp. 459–486). Lawrence Erlbaum.

Ertmer, P. A., & Newby, T. J. (1993). Behaviorism, cognitivism, constructivism: Comparing critical features from an instructional design perspective. *Performance Improvement Quarterly*, *26*(2), 43–71.

European Commission. (2017). *Communication from the commission to the European parliament, the council.* The European Economic and Social Committee and the Committee of the Regions on a Renewed EU Agenda for Higher Education. Retrieved from: https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CElearning environmentX:52017SC0164&from=EN.

Fasko, D. (2001). Education and creativity. *Creativity Research Journal*, *13*(3-4), 317–327.

Finke, R. A., Ward, T. B., & Smith, S. M. (1992). *Creative cognition: Theory, research, and applications.* MIT Press.

Fisher, E., Biviji, M., & Nair, I. (2011). *New perspectives on teaching innovation to engineers: An exploration of mental models of innovation experts.* Proceedings of the 2011 ASEE Annual Conference & Exposition, Vancouver, BC.

Fives, H., & Buehl, M. M. (2012). Spring cleaning for the "messy" construct of teachers' beliefs: What are they? Which have been examined? What can they tell us? In K. R. Harris, S. Graham, & T. Urdan (Vol. Eds.), *APA educational psychology handbook: Individual differences and cultural and contextual factors* (Vol. 2, pp. 471–499). American Psychological Association.

Fraser, B. J. (2007). Classroom learning environments. In S. K. Abell & N. G. Lederman (Eds.), *Handbook of research on science education* (pp. 103–124). Lawrence Erlbaum.

Fraser, B. J. (2012). Classroom learning environments: Retrospect, context and prospect. In B. J. Fraser, K. G. Tobin, & C. J. McRobbie (Eds.), *Second international handbook of science education* (pp. 1191–1239). Springer.

Gann, D. M. (2004). *Housing futures.* In Housing Forum – Constructing Excellence Conference, 3rd Feb 2004, Britannia International Hotel, London.

Gatlin, L. S. (1998). *The effect of pedagogy informed by constructivism: A comparison of student achievement across constructivist and traditional classroom environments* (Doctoral dissertation). Available from ProQuest dissertations and theses database. (UMI No. 9900967).

Glynn, M. (1996). Innovative genius: a framework for relating individual organisational intelligences to innovation. *Academy of Management Journal*, *21*(4), 1081–1111.

Grasso, D., & Burkins, M. B. (2009). *Holistic engineering education: Beyond technology*. Springer.

Gul, R., Cassum, S., Ahmad, A., Khan, S., Saeed, T., & Parpio, Y. (2014). Enhancing educators' skills for promoting critical thinking in their classroom discourses: A randomized control trial. *International Journal of Teaching and Learning in Higher Education*, *26*(1), 37–54.

Halsey, K., Jones, M., & Lord, P. (2006). *What works in stimulating creativity amongst socially excluded young people*. http://www.nfer.ac.uk/nfer/publications/NES01/NCLES01.pdf.

Hansen, E. C. (2006). *Successful qualitative health research: A practical introduction*. Open University Press.

Hamza, M. K., & Griffith, K. G. (2006). Fostering problem solving & creative thinking in the classroom: cultivating a creative mind! *National Forum of Applied Educational Research Journal-Electronic, 19*(3), 1–30.

Herro, M-M. (2017). Innovation tournament as a multidisciplinary activity system to promote the development of innovation competence. *Journal of Professional and Vocational Education, 19*(14), 48–61.

Hondzel, C. M. D. (2013). *Fostering creativity: Ontario teachers' perceptions, strategies, and experiences* (Doctoral dissertation, The University of Western Ontario). Retrieved from http://ir.lib.uwo.ca/cgi/viewcontent.cgi?article=2533&context=etd.

Honebein, P. (1996). Seven goals for the design of constructivist learning environments. In B. Wilson (Ed.), *Constructivist learning environments* (pp. 17-24). Educational Technology Publications.

Horng, J. S., & Hu, M. L. (2009). The impact of creative culinary curriculum on creative culinary process and performance. *Journal of Hospitality, Leisure, Sport & Tourism Education, 8*, 34–46.

Hu, M. L., Horng, J. S., & Teng, C. C. (2016). Developing a model for an innovative culinary competency curriculum and examining its effects on students' performance. *The Journal of Creative Behaviour, 50*(3), 193–202.

Hung, W. (2006). The 3C3R model: A conceptual framework for designing problems in PBL. *The Interdisciplinary Journal of Problem-based Learning, 1*(1). https://doi.org/10.7771/1541-5015.1006.

Hunter, S. T., Cushenbery, L., & Friedrich, T. (2012). Hiring an innovative workforce: A necessary yet uniquely challenging endeavor. *Human Resource Management Review, 22*(4), 303–322.

Hurt, H. T., Joseph, K., & Cook, C. D. (1977). Scales for the measurement of innovativeness. *Human Communication Research, 4*(1), 58–65.

Hsu, L. L. (2007). Conducting clinical post- conference in clinical teaching: A qualitative study. *Journal of Clinical Nursing, 16*(8), 1525–1533. doi:10.1111/j.1365-2702.2006.01751.x.

Ijaiya, N. Y. S., Alabi, A. T., & Fasasi, Y. A. (2010). Teacher education in Africa and critical thinking skills: Needs and strategies. *Social Sciences, 5*(4), 380–385. doi:10.3923/sscience.2010.380.385.

Ishii, N., Suzuki, Y., Fujiyoshi, H., Fujii, T., & Kozawa, M. (2006). A framework for designing learning environments fostering creativity. In A. Mendez-Vilas, A. Solano Martın, J. A. Mesa Gonzalez & J. Mesa Gonzalez (Eds.), *Current developments in technology-assisted education* (pp. 228–232). Formatex.

Jablokow, K. (2001). *The thinking expedition: A course in creativity, innovation and change.* Proceedings of the 2001 ASEE Conference and Exposition, Albuquerque, NM.

Jackson, P. W., & Messick, S. (1967). *Creativity and learning.* Houghton Mifflin.

Jansson, D. G., & Smith, S. M. (1991). Design fixation. *Design Studies, 12*(1), 3–11. doi:10.1016/0142-694X(91)90003-F.

Jeffrey, B. (2006). Creative teaching and learning: towards a common discourse and practice. *Cambridge Journal of Education, 36*(3), 399–414.

Johnson, B., & McClure, R. (2004). Validity and reliability of a shortened, revised version of the Constructivist Learning Environment Survey (CLES). *Learning Environments Research, 7*, 65–80.

Jonassen, D. (1994). Thinking technology. *Educational Technology, 34*(4), 34–37.

Jonassen, D. H. (1999). Designing constructivist learning environments. In C. M. Reigeluth (Ed.), *Instructional-design theories and models: A new paradigm of instructional theory* (pp. 215–240). Lawrence Erlbaum.

Jones, A. (2009). Generic attributes as espoused theory: The importance of context. *Higher Education, 58*(2), 175–191.

Joseph, D. (2004). The practice of design-based research: Uncovering the interplay between design, research, and the real-world context. *Educational Psychologist, 39*(4), 235–242.

Jung, D. (2001). Transformational and transactional leadership and their effects on creativity in groups. *Creativity Research Journal, 13*, 185–195.

Jung, D., & Sosik, J. (2002). Transformational leadership in work groups: The role of empowerment, cohesiveness, and collective efficacy on perceived group performance. *Small Group Research, 33*, 313–336.

Kampylis, P. G., & Valtanen, J. (2010). Redefining creativity: Analyzing definitions, collocations, and consequences. *The Journal of Creative Behavior, 44*(3), 191–214. doi:10.1002/j.21626057.2010.tb01333.x.

Kanter, R. M. (1988). When a thousand flowers bloom: Structural, collective, and social conditions for innovation in organizations. *Research in Organizational Behavior, 10*, 169–211.

Kasule, G. W., Wesselink, R., Noroozi, O., & Mulder, M. (2015). The current status of teaching staff innovation competence in Ugandan universities: Perceptions of managers, teachers, and students. *Journal of Higher Education Policy and Management, 37*(3), 330–343.

Keinänen, M. & Butter, R. P. (2018). Applying a self-assessment tool to enhance personalized development of students' innovation competences in the context of university-company cooperation. *Journal of University Pedagogy, 2,* 1.

Keinänen, M., & Kairisto-Mertanen, L. (2019). Researching learning environments and students' innovation competence. *Education+Training, 61*(1), 17–30.

Keinänen, M., Ursin, J., & Nissinen, K. (2018). How to measure students' innovation competence in higher education: Evaluation of an assessment tool in authentic learning environments. *Studies in Educational Evaluation, 58,* 30–36.

Keller, R. T. (2012). Predicting the performance and innovativeness of scientists and engineers. *Journal of Applied Psychology, 97*(1), 225–233.

Kim, H. B., Fisher, D. L., & Fraser, B. J. (1999). Assessment and investigation of constructivist science learning environments in Korea. *Research in Science and Technological Education, 17,* 239–249.

King, N. (1992). Modelling the innovation process: An empirical comparison of approaches. *Journal of Occupational and Organizational Psychology, 65,* 89–100. doi:10.1111/j.2044-8325.1992.tb00487.x.

Kind, P.M., & Kind, V. (2007). Creativity in science education: Perspectives and challenges for developing school science. *Studies in Science Education, 43,* 1–37.

Kirton, M. (1979). Adaptors and innovators: A description and measure. *Journal of Applied Psychology, 61,* 622–629.

Kivunja, C. (2014). Innovative pedagogies in higher education to become effective teachers of 21st century skills: Unpacking the learning and innovations skills domain of the new learning paradigm. *International Journal of Higher Education, 3*(4), 37–48.

Ko, W. H. (2012). A study of the relationships among effective learning, professional competence, and learning performance in culinary field. *Journal of Hospitality, Leisure, Sport & Tourism Education, 11,* 12–20.

Koen, B. V. (1985). *Definition of the engineering method.* American Society for Engineering Education.

Koh, N. K., & Fraser, B. J. (2014). Learning environment associated with the use of mixed-mode delivery model among secondary business studies students in Singapore. *Learning Environments Research, 17,* 157–171.

Konst, T., & Scheinin, M. (2018). The changing world has implications on the higher education and the teaching profession. *On the Horizon, 26*(1), 1–8.

Kramer, J., Daly, S. R., Yilmaz, S., Seifert, C. M., & Gonzalez, R. (2015). Investigating the impacts of design heuristics on idea initiation and development. *Advances in Engineering Education, 4*(4), Article No. 1. Retrieved from https://advances.asee.org/?publication=investigating-the-impacts-of-design-heuristics-on-idea-initiation-and-development.

Kurtzberg, T. R. & Amabile, T. M. (2000–2001). From Guilford to creative synergy: Opening the black box of team-level creativity. *Creativity Research Journal, 13*(3&4), 285–294.

Kwan, Y., & Wong, A. F. L. (2014). The constructivist classroom learning environment and its associations with critical thinking ability of secondary school students in liberal studies. *Environmental Education Research, 17*, 157–171.

Leavy, B. (2005). A leader's guide to creating an innovation culture. *Strategy and Leadership, 33*, 38-45.

Lee, J. C. K., Zhang, Z., Song, H. & Huang, X. (2013). Effects of epistemological and pedagogical beliefs on the instructional practices of teachers: A Chinese perspective. *Australian Journal of Teacher Education, 38*(12), 120–146.

Lee, S., & Taylor, P. (2001, December). *The cultural adaptability of the CLES: A Korean perspective*. Paper presented at the annual meeting of the Australian Association for Research in Education, Fremantle, Australia.

Leung, A. K. Y., & Chiu, C. Y. (2008). Interactive effects of multicultural experiences and openness to experience on creative potential. *Creativity Research Journal, 20*(4), 376–382.

Lev-Zamir, H., & Leikin, R. (2013). Saying versus doing: Teachers' conceptions of creativity in elementary mathematics teaching. *ZDM, 45*(2), 295–308. http://dx.doi.org/10.1007/s11858-012-0464-4.

Lewis, T., & Zuga, K. F. (2007). *A conceptual framework of ideas and issues in technology education*. Ohio State University.

Li, Z., Cheng, Y., & Lui, C. (2012). A constructionism framework for designing game-like learning systems: Its effect on different learners. *British Journal of Education Technology, 44* (2), 208–224.

Liebenberg, L., & Mathews, E. H. (2010). Integrating innovation skills in an introductory engineering design-build course. *International Journal of Technology Design Education, 22*, 93–111.

Lim, Y. K., & Sato, K. (2006). Describing multiple aspects of use situation: Applications of design information framework (DIF) to scenario development. *Design Studies, 27*, 57–76.

Lincoln, Y., & Guba, E. (1986). Research, evaluation, and policy analysis: heuristics for disciplined inquiry. *Review of Policy Research, 5*, 546–565.

Lissmann, U. (2005). Analysing teachers' thoughts prior to student assessment. In P. M. Denicolo & M. Kompf (Eds.), *Teacher thinking and professional action* (pp. 139–152). Routledge.

Litosseliti, L. (2003). *Using focus groups in research*. Continuum International Publishing Group.

Lubart, T. I. (2001). Models of the creative process: Past, present, and future. *Creativity Research Journal, 13* (3/4), 295–308. doi:10.1207/S15326934CRJ1334_07.

Lumsdaine, E., & Binks, M. (2006). *Entrepreneurship, from creativity to innovation: Thinking skills for a changing world*. Trafford Publishing.

Lumsdaine, E., Lumsdaine, M., & Shelnutt, J. W. (1999). *Creative problem solving and engineering design*. McGraw-Hill.

Mäkinen, M., & Annala, J. (2010). Osaamisperustaisten opetussuunnitelman monet merkitykset korkeakoulutuksessa. *Kasvatus & Aika, 4*, 41–61.

Malaguzzi, L. (1993). History, ideas, and basic philosophy: an interview with Lella Gandini. In C. Edwards, L. Gandini, & G. Forman (Eds.), *The hundred languages of children: The Reggio Emilia approach - Advanced reflections*. Ablex Publishing.

Mansour, M. (2013). Examining patient safety education in pre-registration nursing curriculum: Qualitative study. *Journal of Nursing Education and Practice, 3*(12), 157–167. DOI: 10.5430/jnep.v3n12p157.

Marin-Garcia, J. A., Andreu-Andres, M. A., Atares-Huerta, L., Aznar-Mas, L. E., Garcia-Carbonell, A., Gonzalez-Ladron-de-Guevara, F. & Watts, F. (2016). Proposal of framework for innovation competencies development and assessment (FINCODA). *WPOM-Working Papers on Operations Management, 7*(2), 119–126. https://doi.org/10.4995/wpom.v7i2.6472.

Marin-Garcia, J., Pérez-Peñalver, J., & Watts, F. (2013). How to assess innovation competence in services: The case of university students. *Direccion y Organization, 50*, 48–62.

Martindale, C. (1999). Biological bases of creativity. In R. Sternberg (Ed.), *Handbook of creativity* (pp. 137–152). Cambridge University Press.

Martin-Dunlop, C., & Fraser, B. J. (2008). Learning environment and attitudes associated with an innovative course designed for prospective elementary teachers. *International Journal of Science and Mathematics Education, 6*, 163–190.

McKenney, S., Nieveen, N., & van den Akker, J. (2006). Design research from a curriculum perspective. In J. van den Akker, K. Gravemeijer, S. McKenney, & N. Nieveen (Eds.), *Educational design research* (67–90). Routledge.

McKenney, S., & Reeves, J. (2019). *Conducting educational design research*. Routledge.

McLellan, R., & Nicholl, B. (2012). Creativity in crisis in design & technology: Are classroom climates conducive for creativity in English secondary schools? *Thinking Skills and Creativity, 9*, 165–185. doi:10.1016/j.tsc.2012.11.004.

Messmann, G., & Mulder, R. H. (2011). Innovative work behavior in vocational colleges: Understanding how and why innovations are developed. *Vocations and Learning, 4*(1), 63–84. doi:10.1007/s12186-010-9049-y.

Messmann, G., & Mulder, R. H. (2012). Development of a measurement instrument for innovative work behavior as a dynamic and context-bound construct. *Human Resource Development International, 15*(1), 43–59. doi:10.1080/13678868.2011.646894.

Messmann, G., & Mulder, R. H. (2014). Exploring the role of target specificity in the facilitation of vocational teachers' innovative work behaviour. *Journal of Occupational and Organizational Psychology, 87*(1), 80–101. https://doi.org/10.1111/joop.12035.

Meyer, A. A., & Lederman, N. G. (2013). Inventing creativity: An exploration of the pedagogy of ingenuity in science classrooms. *School Science and Mathematics, 113*(8), 400–409.

Michael, J. (2006). Where's the evidence that active learning works? *Advances in Physiology Education, 30*(4), 159–167.

Morais, M. F., & Azevedo, I. (2011). What is a creative teacher and what is a creative pupil? Perceptions of teachers. *Procedia Social and Behavioral Sciences, 12,* 330–339. doi:10.1016/j.sbspro.2011.02.042.

Morse, J. M., & Field, P. A. (1995). *Qualitative research methods for health professionals* (2nd ed). Sage.

Mullet, D. R., Willerson, A., Lamb, K. N., & Kettler, T. (2016). Examining teacher perceptions of creativity: a systematic review of the literature. *Thinking Skills and Creativity, 21,* 9–30.

Mumford, M., & Gustafson, S. (1988). Creativity syndrome: Integration, application and innovation. *Psychological Bulletin, 103*(1), 27–43.

Mumford, M. D., Mobley, M. I., Uhlman, C. E., Reiter-Palmon, R., & Doares, L. (1991). Process analytic models of creative capacities. *Creativity Research Journal, 4*, 91–122.

Newton, D. P. (2013). Moods, emotions and creative thinking: A framework for teaching. *Thinking Skills and Creativity, 8*, 34–44.

Newton, D. P., & Newton, L. D. (2009). Some student teachers' conceptions of creativity in school science. *Research in Science and Technological Education, 27*(1), 45–60.

Nielsen, J. A. (2015). Assessment of innovation competency: A thematic analysis of upper secondary school teachers' talk. *The Journal of Educational Research, 108*, 318–330.

Nix, R. K., Fraser, B. J., & Ledbetter, C. E. (2005). Evaluating an integrated science learning environment using the Constructivist Learning Environment Survey. *Learning Environments Research, 8,* 109–133.

Nussbaum, B., Berner, R., & Brady, D. (2005). Get creative! How to build innovative companies and a creative corporation. *Business Week, 8*(15), 51–68.

OECD. (2016). *Getting skills right: Anticipating and responding to changing skill needs.* OECD Publishing. http://dx.doi.org/10.1787/9789264252073-en.

Olafson, L. J., & Schraw, G. (2006). Teachers' beliefs and practices within and across domains. *International Journal of Educational Research*, *45*, 71–84.

Osborn, A. F. (1963). *Applied imagination.* Scribner.

Ovbiagbonhia, A. R., Kollöffel, B. J., & den Brok, P. (2019). Educating for innovation: students' perceptions of the learning environment and of their own innovation competence. *Learning Environments Research, 22,* 387–407. DOI 10.1007/s10984-019-09280-3.

Ovbiagbonhia, A. R., Kollöffel, B. J., & den Brok, P. (2020). Teaching for innovation competence in higher education Built Environment engineering classrooms: Teachers' beliefs and perceptions of the learning environment. *European Journal of Engineering Education, 45*(6), 917–936. https://doi.org/10.1080/03043797.2020.1784097.

Ozkal, K., Tekkaya, C., Cakiroglu, J., & Sungur, S. (2009). A conceptual model of relationships among constructivist learning environment perceptions, epistemological beliefs, and learning approaches. *Learning and Individual Differences*, *19*, 71–79.

Park, S., Lee, S., Oliver, J. S., & Cramond, B. (2006). Changes in Korean science teachers' perceptions of creativity and science teaching after participating in an overseas professional development program. *Journal of Science Teacher Education*, *17*, 37–64.

Passig, D., & Cohen, L. (2014). Measuring the style of innovative thinking among engineering students, *Research in Science & Technological Education*, *32*(1), 56–77, DOI:10.1080/02635143.2013.878328.

Patterson, F., Kerrin, M., & Gatto-Roissard, G. (2009). *The characteristics and behaviours of innovative people in organisations.* NESTA.

Paulhus, D. L., & Vazire, S. (2007). The self-report method. In R. W. Robins, R. C. Fraley, & R. F. Krueger (Eds), *Handbook of research methods in personality psychology* (pp. 224-239). The Guilford Press.

Paulus, P. B., & Nijstad, B. A. (2003). Group creativity – An introduction. In P. B. Paulus & B. A. Nijstad (Eds.), *Group creativity: Innovation through collaboration* (pp. 3–12). Oxford University Press.

Penttilä, T. (2016). Developing educational organizations with innovation pedagogy. *IJAEDU-International E-Journal of Advances in Education*, *2*(5), 259–267.

Penttilä, T., & Kairisto-Mertanen, L. (2012). Innovation competence barometer ICB – A tool for assessing students' motivation competencies as learning outcomes in higher education area. In *INTED2012 Proceedings, 6th International Technology, Education and Development Conference, Valencia, Spain. 5–7 March, 2012* (pp. 6347–6351). IATED.

Pérez-Penalver, M. J., Aznar-Mas, L. E., & Montero-Fleta, B. (2018). Identification and classification of behavioral indicators to assess innovation competence. *Journal of Industrial Engineering and Management, 11*(1), 87–115.

Phillips, N., & Duke, M. (2001). The questioning skills of clinical teachers and preceptors: A comparative study. *Journal of Advanced Nursing, 33*, 523-529. doi:10.1046/j.1365-2648.2001.01682.x.

Pikkarainen, E. (2014). Competence as a key concept of educational theory: A semiotic point of view. *Journal of Philosophy of Education, 48*(4), 621–636.

Plucker, J. A., Beghetto, R. A., & Dow, G. T. (2004). Why isn't creativity more important to educational psychologists? Potentials, pitfalls, and future directions in creativity research. *Educational Psychologist, 39*(2), 83–96. doi:10.1207/s15326985ep3902_1.

Plucker, J. A., Kaufman, J. C., & Beghetto, R. A. (2015). *What we know about creativity?* Retrieved from http://www.p21.org/storage/documents/docs/Research/P21_4Cs_Research_Brief_Series_-_Creativity.pdf.

Plucker, J. A., & Makel, M. C. (2010). Assessment of creativity. In J. C. Kaufman (Ed.). *The Cambridge handbook of creativity* (pp. 48-73). Cambridge University Press.

Posner, G. J., & Rudnitsky, A. N. (2006). *Course design: A guide to curriculum development for teachers*. Pearson Education.

Price, L. L., & Ridgway, N. M. (1983). Development of a scale to measure use innovativeness. *Advances in Consumer Research, 10*(1), 679–684.

Profetto-McGrath, J., Bulmer, S. K., Day, R. A., & Yonge, O. (2004). The questioning skills of tutors and students in a context based baccalaureate nursing program. *Nurse Education Today, 24*(5), 363–372. doi:10.1016/j.nedt.2004.03.004.

Ragusa, G. (2011). *Engineering creativity and propensity for innovative thinking in undergraduate and graduate students*. Paper presented at the 2011 Annual Conference & Exposition, Vancouver, B.C., CA.

Richardson, C., & Mishra, P. (2018). Learning environments that support student creativity: Developing the SCA learning environment. *Thinking Skills and Creativity, 27*, 45–54.

Richardson, V. (1996). *The role of attitudes and beliefs in learning to teach*. In J. Sikula (Ed.), *Handbook of research on teacher education* (pp. 102–119). Simon and Schuster Macmillan.

Robinson, K. (2011). *Out of our minds*. Capstone Publishing.

Robinson, M. (2001). It works, but is it action learning? *Education and Training, 43*(2), 64–71.

Rogers, E. M. (2003). *Diffusion of innovations* (5th ed.). Free Press.

Root-Bernstein, R. S. (2003). Nepistemology: Problem generation and evaluation. In L. V. Shavanina (Ed.), *International handbook on innovation* (pp. 170–179). Elsevier.

Root-Bernstein, R. S., & Root-Bernstein, M. (2017). People, passions, problems: The role of creative exemplars in teaching for creativity. In R. A. Beghetto & B. Sriraman (Eds.), *Creative contradictions in education*. (pp. 143–164). Springer.

Rubenstein, L. D., McCoach, D. B., & Siegle, D. (2013). Teaching for creativity scales: an instrument to examine teachers' perceptions of factors that allow for the teaching of creativity. *Creativity Research Journal, 25*, 324–334. http://dx.doi.org/10.1080/10400419.2013.813807.

Runco, M. A. (2003). Education for creative potential. *Scandinavian Journal of Educational Research, 47*(3), 317–324.

Runco, M. A. (2004). Everyone has creative potential. In R. J. Sternberg, E. L. Grigorenko, & J. L. Singer (Eds.), *Creativity: From potential to realization* (pp. 21–30). American Psychological Association.

Runco, M. A. (2007). *Creativity: theories and themes: research, development, and practice*. Elsevier Academic Press.

Runco, M. A., & Albert, R. S. (2010). Creativity research: a historical view. In J. C. Kaufman, J. Caaa, & R. J. Sternberg (Eds.). *The Cambridge handbook of creativity* (pp. 3–19). Cambridge University Press.

Rutland, M., & Barlex, D. (2008). Perspectives on pupil creativity in design and technology in the lower secondary curriculum in England. *International Journal of Technology and Design Education, 18*, 139–165.

Ryan, R. M., & Deci, E. L. (2000). Motivation. *Contemporary Educational Psychology, 25*, 54–67.

Sadler, D. R. (1998). Formative assessment: revisiting the territory. *Assessment in Education, 5*(1), 77–84. Sahlberg, P. (2009). Creativity and innovation through lifelong learning. *Lifelong Learning in Europe, 14*(1), 53–60.

Sandoval, W. A., & Bell, P. (2004). Design-based research methods for studying learning in context: Introduction. *Educational Psychologist, 39*(4), 199–201.

Savasci, F., & Berlin, D. F. (2012). Science teacher beliefs and classroom practice related to constructivism in different school settings. *Journal of Science Teacher Education, 23*, 65–86.

Sawyer, K. (2011). The cognitive neuroscience of creativity: A critical review. *Creativity Research Journal, 23*(2), 137–154. DOI: 10.1080/10400419.2011.571191.

Sawyer, R. K. (2006). Educating for innovation, *Thinking Skills and Creativity, 1*, 41–48.

Sawyer, R. K. (Ed.). (2014). *Cambridge handbook of the learning science* (2nd ed.). Cambridge University Press.

Sawyer, R. K. (2012). *Explaining creativity: The science of human innovation* (2nd ed.). Oxford University Press.

Saylan, A., Armağan, F. Ö., & Bektaş, O. (2016). The relationship between pre-service science teachers' epistemological beliefs and preferences for creating a constructivist learning environment. *European Journal of Science and Mathematics Education, 4*(2), 251–267.

Schön, D. A. (1987). *Educating the reflective practitioner.* John Wiley & Sons.

Scott, K. A. (2015). *Creativity: conceptions of a group of exemplary teachers* (Unpublished doctoral dissertation). The University of North Carolina, Greensboro.

Scott, S. G., & Bruce, R. A. (1994). Determinants of innovative behavior: A path model of individual innovation in the workplace. *Academy of Management Journal, 37*(3), 580–607.

Scott, G., Leritz, L. E., & Mumford, M. D. (2004). The effectiveness of creativity training: A quantitative review. *Creativity Research Journal, 16*, 361–388.

Sefton-Green, J., & Sinker, R. (Eds.). (2000). *Evaluating creativity: Making and learning by young people.* Routledge.

Sellappah, S., Hussey, T., Blackmore, A. M., & McMurray, A. (1998). The use of questioning strategies by clinical teachers. *Journal of Advanced Nursing, 28*(1), 142–148. doi:10.1046/j.1365- 2648.1998.00776.x.

Shaheen, R. (2011). *The place of creativity in Pakistani primary education system: An investigation into the factors enhancing and inhibiting primary school children's creativity* (Doctoral dissertation, University of Birmingham). Retrieved from http://files.eric.ed.gov/fulltext/ED522273.pdf.

Shavelson, R. J. (2003). On the science of education design studies. *Educational Researcher, 32*(1), 25–28.

Shavelson, R. J., & Stern, P. (1981). Research on teachers' pedagogical thoughts, judgements, decisions, and behaviour. *Review of Educational Research, 51*, 455–498.

Sheppard, S. D., Macatangay, K., Colby, A., & Sullivan, W. M. (2009). *Educating engineers: Designing the future of the field.* The Carnegie Foundation for the Advancement of Teaching.

Simplicio, J. S. C. (2000). Teaching classroom educators how to be more effective and creative teachers. *Education, 120*(4), 675–680.

Slimane, M. (2015). Relationship between innovation and leadership. In *Procedia - Social and Behavioral Sciences of the 3rd International Conference on Leadership, Technology and Innovation Management, 181* (pp. 218 – 227).

Smith, G. F. (2003). Towards a logic of innovation. In L. V. Shavinina (Ed.), *The international handbook on innovation* (pp. 347–365). Elsevier.

Smith, J. A., Flowers, P., & Larkin, M. (2009). *The interpretative phenomenological analysis: Theory, method and research.* Sage Publications.

Son, L. K., & Simon, D. A. (2011). Distributed learning: Data, metacognition, and educational implications. *Educational Psychology Review, 24*, 379–399.

Spinner, H., & Fraser, B. J. (2005). Evaluation of an innovative mathematics program in terms of classroom environment, student attitudes, and conceptual development. *International Journal of Science and Mathematics Education, 3*, 267–293.

Sternberg, R. J. (2012). The assessment of creativity: An investment-based approach. *Creativity Research Journal, 24*(1), 3–12.

Sternberg, R. J., & Lubart, T. (1995). *Defying the crowd: Cultivating creativity in a culture of conformity*. Free Press.

Sternberg, R. J., & Lubart, T. I. (1999). The concept of creativity: Prospects and paradigms. In R. J. Sternberg (Ed.), *Handbook of creativity* (pp. 3–15). Cambridge University Press.

Sternberg, R. J., & Williams, W. M. (1996). *How to develop student creativity*. Association for Supervision and Curriculum Development.

Stouffer, W. B., Russel, J., & Oliva, M. G. (2004). Making the strange familiar: Creativity and the future of engineering education. *Proceedings of the 2004 American Society for Engineering education Annual Conference & Exposition, Salt Lake City, UT*.

Swartz, R., & Parks, S. (1994). *Infusing the teaching of critical and creative thinking into content instruction: A lesson design handbook for the elementary grades.* Critical Thinking Press and Software.

Tabak, F., & Barr, S. H. (1999). Propensity to adopt technological innovations: the impact of personal characteristics and organizational context. *Journal of Engineering and Technology Management, 16*, 247–270.

Taylor, P., Dawson, V., & Fraser, B. (1995, April). *A constructivist perspective on monitoring classroom learning environments under transformation*. Paper presented at the Annual Meeting of the American Educational Research Association, San Francisco, CA.

Taylor, P., Fraser, B., & Fisher, D. (1997). Monitoring constructivist classroom learning environments. *International Journal of Educational Research, 27*(4), 293–302.

Taylor, P. C., Fraser, B. J., & White, L. (1994, April). *A classroom learning environment questionnaire for science educators interested in the constructivist reform of school science.* Paper presented at the annual meeting of the National Association for Research in Science Teaching, Anaheim, CA.

Thao-Do, T. P., Thi Bac-Ly, D., & Yuenyong, C. (2016). Learning environment in Vietnamese physics teacher education programme through the lens of constructivism: A case study of a state university in Mekong Delta region, Vietnam. *International Journal of Science and Mathematics Education, 14*(1), 55–79.

Tidd, J. & Bessant, J. (2009). *Managing innovation* (4th Ed.). John Wiley and Sons.

Tierney, P., & Farmer, S. M. (2002). Creative self-efficacy: Its potential antecedents and relationship to creative performance. *Academy of Management Journal, 45*(6), 1137-1148.

Tierney, P., & Farmer, S. M. (2011). Creative self-efficacy development and creative performance over time. *Journal of Applied Psychology, 96*, 277–293.

Tolbert, D. A., & Daly, S. R. (2013). First-year engineering student perceptions of creative opportunities in design. *International Journal of Engineering Education, 29*(4), 879–890.

Topolovčan, T., Matijević, M., & Dumančić M. (2016). Some predictors of constructivist teaching in elementary education. *Croatian Journal of Education, 18*(1/2016), 193–212.

Torrance, E. P. (1962). *Guiding creative talent*. Prentice-Hall.

Torrance, E. P. (1972). Teaching for creativity. *Journal of Creative Behavior, 6*, 114–143.

Torrance, E. P., & Myers, R. E. (1973). *Creative learning and teaching*. Dodd, Mead.

Treffinger, D., Young, G., Shelby, E., & Shepardson, C. (2002). *Assessing creativity: A guide for educators*. Storrs, CT: The National Research Center on the Gifted and Talented.

Trilling, B., & Fadel, C. (2009). *21st century skills: Learning for life in our times*. Jossey-Bass.

Tynjälä, P. (1999). Towards expert knowledge? A comparison between a constructivist and a traditional learning environment in the university. *International Journal of Educational Research, 31*(5), 357–442.

Tynjälä, P., Välimaa, J., & Sarja, A. (2003). Pedagogical perspectives on the relationship between higher education and working life. *Higher Education, 46*, 147–166.

Unsworth, K. L., Brown, H., & McGuire, L. (2000). Employee innovation: The roles of idea generation and idea implementation. In *The Annual Conference of the Society for Industrial and Organizational Psychology*, 2000-04-14 - 2000-04-17.

Ursin, J., & Hyytinen, H. (2010). Mitä korkeakoulutuksessa opitaan? Esimerkkinä AHELO. In R. Laukkainen (Eds.) *PISA, PIAAC, AHELO. Miksi ja miten OECD mittaa osaamista?* Opetus- ja kulttuuriministeriön julkaisuja 17, Yliopistopaino, (pp. 65–70).

Van den Akker, J., Gravemeijer, K., McKenney, S., & Nieveen, N. (Eds.). (2006). *Educational design research*. Routledge.

Van Merriënboer, J. J. G., & Kirschner, P. A. (2007). *Ten steps to complex learning: A systematic approach to four component instructional design*. Lawrence Erlbaum Associates.

Vazire, S. (2010). Who knows what about a person? The self-other knowledge asymmetry (SOKA) model. *Journal of Personality and Social Psychology, 98*, 281–300. doi:10.1037/a0017908.

Vennix, J., den Brok, P., & Taconis, R. (2017). Perceptions of STEM-based outreach learning activities in secondary education. *Learning Environments Research, 20*, 21–46.

Victor, S. (2016). *Distributed learning: A flexible learning model for a global economy*. Obsidian Learning. Retrieved June 13, 2016, from http://obsidianlearning.com/wp-content/uploads/2016/02/Obsidian- Distributed-Learning-Model.pdf.

Vila, L. E., Perez, P. J., & Morillas, F. G. (2012). Higher education and the development of competencies for innovation in the workplace. *Management Decision, 50*(9), 1634–1648.

Virtanen, A., & Tynjälä, P. (2016). *Factors explaining learning of generic skill: a study of university students' experiences.* Paper presented at the Higher Education Conference, The Scholarship of Learning, Teaching & Organizing, Amsterdam, July 13-15.

Voland, G. (2004). *Engineering by design.* Pearson Education.

Wagner, T. (2010). *The global achievement gap: Why even our best schools don't teach the new survival skills our children need–and what we can do about it.* Basic Books.

Wahyudi, M., & Treagust, D. F. (2003). The status of science classroom environments in Indonesian lower secondary schools. *Learning Environments Research, 7,* 43–63.

Wang, P., Rode, J. C., Shi, K., Luo, Z., & Chen, W. (2013). A workgroup climate perspective on the relationships among transformational leadership, workgroup diversity, and employee creativity. *Group Organization Management, 38*(3), 334–360.

Ward, M., Gruppen, L., & Regehr, G. (2002). Measuring self-assessment: current state of art. *Advances in Health Sciences Education, 7,* 63–80.

Watts, F., Marín-García, J., García-Carbonell, A., & Aznar-Mas, L. E. (2012). Validation ofa rubric to assess innovation competence. *Working Papers on Operations Management, 3*(1), 61–70.

West, M. A. (2002). Sparkling fountains or stagnant ponds: An integrative model of creativity and innovation implementation in work groups. *Applied Psychology: An International Review, 51*(3), 355-424.

West, M. A., & Farr, J. L. (1989). Innovation at work: Psychological perspectives. *Social Behavior, 4,* 15–30.

West, M. A., & Farr, J. L. (Eds.). (1990). *Innovation and creativity at work.* John Wiley.

West, R. E., Tateishi, I., Wright, G., & Fonoimoana, M. (2012). Innovation 101: Promoting undergraduate innovation through a two-day boot camp. *Creativity Research Journal, 24*(2), 243–251. DOI: 10.1080/10400419.2012.677364.

Wilcox-Herzog, A. (2002). Is there a link between teachers' beliefs and behaviors? *Early Education and Development, 13* (1), 81–106.

Wink, D. M. (1993). Effect of a program to increase the cognitive level of questions asked in clinical post conferences. *Journal of Nursing Education, 32*(8), 357–363.

Wood, R., & Ashfield, J. (2008). The use of the interactive whiteboard for creative teaching and learning in literacy and mathematics: A case study. *British Journal of Educational Technology, 39*(1), 84–96.

Woolley, S. L., Benjamin, W. J. J., & Woolley, A. W. (2004). Construct validity of a self-report measure of teacher beliefs related to constructivist and traditional approaches to teaching and learning. *Educational and Psychological Measurement, 64*, 319–331.

Wright, G. A., Skaggs, P., & West, R. E. (2013). Teaching innovation in high school technology classes. *The Technology and Engineering Educator, 72*(4), 18–23.

Wubbels, T., Brekelmans, M., den Brok, P., & van Tartwijk, J. (2006). An interpersonal perspective on classroom management in secondary classrooms in the Netherlands. In C. M. Evertson & C. S. Weinstein (Eds.), *Handbook of classroom management: Research, practice and contemporary issues* (pp.1161–1191). Erlbaum.

Xue, X., Zhang, R., Yang, R. & Dai, J. (2014). Innovation in construction: A critical review and future research. *International Journal of Innovation Science*, *6*(2), 111–126. https://doi.org/10.1260/1757-2223.6.2.111.

Zell, E., & Križan, Z. (2014). Do people have insight into their abilities? A metasynthesis. *Perspectives on Psychological Science*, *9*, 111–125.

Zenobia, C. Y. (2013). A systematic review of creative thinking/creativity in nursing education. *Nurse Education Today*, *33*(11), 1382–1387.

Zimmerman, B. J. (2006). Development and adaptation of expertise: The role of self-regulatory processes and beliefs. In K. A. Ericsson, N. Charness, P. Feltovich, & R. R. Hoffman (Eds.), *The Cambridge handbook of expertise and expert performance* (pp. 705–722). Cambridge University Press.

Appendices

Appendix A

Students' survey version – Innovation competence learning environments mapping tool

This appendix presents the English translation of the Netherlands version of the directions, items and responses used in the first study. The Netherlands/English versions are available from the author.

Q1. The following questions will give you the opportunity to tell us about your background so that we can understand the context of your provided answers.
What is your gender?

o Male (1)

o Female (2)

Q2. What is your age in years?

____

Q3. At which university of applied science are you studying?

o Alkmaar

o Amsterdam

o Etc.

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Q4. In which faculty/department are you studying? If you study in more than one faculty/department, please choose the faculty/department of your major study specialisation.

o Archaeology

o Architecture

o Etc.

Q5. What major area of study are you studying at this school?
In case your area does not appear in the list below, please mark the item you think best fit your major area of study or specify it in the space provided below.

o Archaeology

o Architecture

o Etc.

Q6. Please indicate your current year of study.

- o Year 1
- o Year 2
- o Year 3
- o Year 4

Classroom learning environments survey (CLEs)

All items used the response alternatives of strongly agree (7), agree, somewhat agree, neither agree nor disagree, somewhat disagree, disagree and strongly disagree (1).

Q7. With respect to the classroom environment of your major area of study, please indicate the extent to which you agree or disagree with the following statements.

Learning about the world (Personal Relevance)

1. In my studies within my major, I learn about the world beyond the work field of Built Environment in order to become innovative.
2. In my studies within my major, new learning about innovation starts with problems about the world beyond the work field of Built Environment.
3. In my studies within my major, students make things for other people to use beyond the work field of Built Environment.
4. In my studies within my major, students learn to reflect on innovative solutions in Built Environment fields.

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Learning about science (Uncertainty)

1. In my studies within my major, students learn how an innovative solution has changed over time.
2. In my studies within my major, students learn that innovation is influenced by people's values and opinions.
3. In my studies within my major, students learn about the different innovative techniques used by people in other areas.
4. In my studies within my major, students learn that modern science is different from the science of long ago.
5. In my studies within my major, students learn that innovation is about creating new and implementable solutions.

Learning to communicate (Student Negotiation)

1. In my studies within my major, students discuss with other students how to solve problems innovatively.
2. In my studies within my major, students explain their understandings of innovative processes to one another.

Innovation competence questionnaire

All items used the response alternatives of strongly agree (7), agree, somewhat agree, neither agree nor disagree, somewhat disagree, disagree and strongly disagree (1).

Q8. With respect to your innovation competence, please indicate the extent to which you agree or disagree with the following statements.

Creativity

1. I consider myself to be creative and original in my thinking and behavior.
2. I am an inventive kind of person.
3. I seek out new ways of doing things.
4. I enjoy trying out new ideas.
5. I find it stimulating to be original in my thinking and behavior.
6. I am receptive to new ideas.
7. I frequently improvise methods of solving a problem when an answer is not apparent.

Leadership

1. I feel that I am an influential member of my peer group.
2. My peers often ask me for advice or information.
3. I enjoy taking part in leadership responsibilities of the group I belong to.

Energy

1. It's energizing when you are given rewards for good work (e.g., a school day trip).
2. I feel really motivated when I produce something that no one else has.
3. I feel really enthusiastic about my chosen subjects.
4. It's energizing and rewarding to help other people.
5. I really push myself to achieve good grades.
6. When I'm doing something, I like to feel it has a purpose or goal.
7. I have lots of energy for work and play.

Creative self-efficacy

1. I have confidence in my ability to solve problems creatively.
2. I feel that I am good at generating novel ideas.
3. I have a knack for further developing the ideas of others.

Risk propensity

1. When I make choices, I want to be as sure as possible what the future consequences will be for me.
2. I want my work to provide me with opportunities to show that I can overcome problems.
3. I would not take a risk on an activity that might spoil my chances of getting good grades at school/college.
4. Fearing that I might fail my exams is a powerful motivator at school/college.

Ambiguities and problems

1. I am challenged by unanswered questions.
2. I am challenged by ambiguities and unsolved problems.

Focus on innovation competence curriculum level questionnaire

Q9. The following section will give you the opportunity to tell us the extent to which your school fosters students' innovation competence at the curriculum and classroom level.

By innovation competence, we mean the capability to create novel, new and implementable solutions to a practical problem.

1. At my school, innovation competence is an end goal.
2. At my school, improving students' innovation competence is part of our school's mission.
3. At my school, a part of the curriculum (for example, a course, assignment, etc.) is specially devoted to enhancing students' innovation competence.
4. At my school, students' innovation competence is assessed.

Relevance of teaching for innovation competence

Q10. Do you think that it is relevant to be taught how to become innovative in your current area of study? Please indicate the extent to which you think it is relevant or irrelevant.

- o Very irrelevant
- o Irrelevant
- o Somewhat Irrelevant
- o Neither relevant nor irrelevant
- o Somewhat relevant

- o Relevant
- o Very relevant

Q11 Are you being taught how to become innovative in your major area of study in this school in this school year?

We want you to respond about the major area of study you identified/specified in Q5.

- o Yes
- o No

Q12 If yes, please specify briefly the (course/subject/module/minor/major) name and study year of the course(s).

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Appendix B

Teachers' survey version – Innovation competence learning environments mapping tool

This appendix presents the English translation of the Netherlands version of the directions, items and responses used in the second study. The Netherlands/English versions are available from the author.

Q1. The following questions will give you the opportunity to tell us about your background so that we understand the context of your provided answers.
What is your gender?

- o Male
- o Female

Q2. What is your age in years?

____

Q3. What is the highest level of education that you have completed?

- o Secondary vocational education (MBO)
- o Applied university/ higher vocational education (HBO)
- o University education (WO)
- o Doctoral degree (PhD)
- o Other, please specify in the box below ______________________________

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Q4. Could you please specify below the country in which you completed your highest level of education?

____

Q5. At which university of applied science are you teaching? If you teach at more than one university, please choose the university where you have the most teaching time.

- o Alkmaar
- o Amsterdam
- o Etc.

Q6. How long in years have you been working as a teacher at this faculty/department/school? Where possible, exclude extended periods of absence (e.g., career breaks).

____

Q7. In which faculty/department/school are you teaching? If you teach in more than one faculty/department/school, please choose the faculty/department/school where you have the most teaching time.

- o Archaeology
- o Architecture
- o Etc.
- o Other, please specify? ____

Q8. How long in years have you been working as a teacher?
Where possible, exclude extended periods of absence (e.g., career breaks).

____

Q9. Do you have other jobs besides being a teacher?

- o Yes, please specify your other job in the space provided ____________________________
- o No

Focus on innovation competence at curriculum level (FIC)
All items used the response alternatives of strongly agree (7), agree, somewhat agree, neither agree nor disagree, somewhat disagree, disagree and strongly disagree (1).

Q10. The following section will give you the opportunity to tell us the extent to which your school fosters students' innovation competence.
By students' innovation competence, we mean the competence to create novel, new and implementable solutions to a practical problem.
Please indicate the extent to which you agree or disagree with the following statements.with respect to your school's curriculum and innovation competence during this school year,

- o At my school, innovation competence is an end goal.
- o At my school, improving students' innovation competence is part of our school's mission.
- o At my school, a course has been specially created to enhance students' innovation competence.
- o At my school, students' innovation competence is assessed.

Relevance of innovation competence instruction (RICT) Q11 – Q13
Q11. How relevant do you think that it is to teach students how to become innovative in your teaching area(s)? Please indicate the extent to which you think it is relevant or irrelevant.

- o Very irrelevant
- o Irrelevant

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- o Somewhat irrelevant
- o Neither relevant nor irrelevant
- o Somewhat relevant
- o Relevant
- o Very relevant

Q12. Are you deliberately teaching your students how to become innovative in your teaching subject area(s) at this school in this school year?

- o Yes
- o No (if no, please move on to Q14)

Q13. If yes, please specify briefly the course(s)/subject(s)/module(s) name and study year of the course(s)

____

Constructivist Learning environments (ClEs)
All items used the response alternatives of strongly agree (7), agree, somewhat agree, neither agree nor disagree, somewhat disagree, disagree and strongly disagree (1).

Q14. With respect to a classroom environment that supports innovation competence, please indicate the extent to which you agree or disagree with the following statements.
Learning about the world (Personal Relevance)

- o In my class, students learn about the world beyond the work field of Built Environment in order to become innovative.
- o In my class, new learning about innovation starts with problems about the world beyond the work field of Built Environment.
- o In my class, students make things for other people to use beyond the work field of Built Environment.
- o In my class, students learn to reflect on innovative solutions in Built Environment fields.

Learning about science (Uncertainty)

- o In my class, students learn how an innovative solution has changed over time.
- o In my class, students learn that innovation is influenced by people's values and opinions.
- o In my class, students learn about the different innovative techniques people use in other areas.
- o In my class, students learn that modern science is different from the science of long ago.

- In my class, students learn that innovation is about creating new and implementable solutions.
- Learning to communicate (Student Negotiation)
- In my class, students discuss with other students how to solve problems innovatively.
- In my class, students explain their understandings of innovation processes to one another.

Adopted from Tierney and Farmer (2002) "creative self-efficacy" (CSE)
All items used the response alternatives of strongly agree (7), agree, somewhat agree, neither agree nor disagree, somewhat disagree, disagree and strongly disagree (1).

Q15. With respect to your ability to teach creatively, please indicate the extent to which you agree or disagree with the following statements.
- I have confidence in my ability to solve students' learning problems creatively.
- I feel that I am good at generating teaching ideas that support students' innovative thinking.
- I have a knack for further developing the innovative ideas of my students.
- I am confident in my ability to teach my students how to become innovative.
- I am confident in my ability to assess my students' innovation competence.

Appendix C

Task prologue - Students' learning activities for innovation competence

This appendix presents the English translation of the Netherlands version of the task used in the third study. The Netherlands/English versions are available from the author.

Introduction

For the organizational professional assignment, each group is required to develop an advisory report. As a result, you will need to conduct in-depth studies about concepts and strategies for making a home or a group of homes (neighbourhood) more sustainable and for making them life-course proof.

However, it appears that making the Built Environment more sustainable is not simply a matter of applying a few tricks. The initial situation is different for each project and specific solutions for the problem must be developed. You will need to develop appropriate concepts for your stated problem. Even though certain already-made concepts are available, a great deal of innovative power will still be required of you during implementation.

As a future structural engineer, you are expected to be able to come up with and implement new solutions. For this, it is necessary to be innovative. You have already been innovative in past courses, but it was usually an unconscious process. In this course, we will help to train you in the knowledge and skills needed for this. It is <u>not</u> an extra assignment; with the instructions, we will help you to arrive at the required innovative solutions in a short time. The focus is on the *energetic revitalization* of the homes and the neighbourhood.

The explicit intention is for you to follow the instructions <u>step by step</u>. Three phases have been defined. A general description of what must be done is given for each phase. This is followed by a step-by-step plan in which the intermediate steps are defined. It is important that everyone adhere to the timetable, otherwise co-creation cannot occur. This requires commitment and discipline, but leads to an absolute increase in the value of the process.

A few phases are missing for a complete innovation process: prototype, test phase, implementation and market *diffusion*. Unfortunately, these phases cannot be practiced in a theoretical setting. That could be done during the minor or during graduation.

A project environment has been created on *EducationOnline* (the same as for the construction grant assignment for course 7).

The process and results are going to be assessed (assessment form). The assessment falls into two parts: assessment result and assessment process. Basically, the final grade is determined by part 2 of the assessment (assessment of the result). Assessment part 1 is intended as feedback for the group, unless the result of part 2 is unsatisfactory; then the final grade is determined on the basis of part 1. Groups who accept the (personal) invitation to pitch on the theme day will be assessed in any case (bonus points).

Planning (deadlines)

Phase A: formulate problem definitions (discussion of project environment, week 1) and provide feedback (discussion of project environment, week 2).
Phase B: generate solutions through 'creative sessions', publish solution ideas (file on the project environment, week 3), further development and redevelopment (week 4).
Phase C: publish test method for solution idea (project environment file, week 5) implement solution idea in the advisory report (week 6) and hand in the log (final submission, week 8).

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Appendix D

Example 1 - making homes energy-neutral

This appendix presents the English translation of the Netherlands version of the task used in third study. The complete Netherlands/English versions are available from the author.

Problem exploration

Each group of six students is instructed to make an analysis and description of the problems surrounding making homes energy-neutral by means of thorough observation and questioning concerning the problems (starting situation, need). The product of this phase is a clearly defined problem.

Steps that are highlighted are intended to be done individually. This increases the yield. It is important not to influence each other in this, otherwise group thinking will arise.

Highlighted text fragments describe a possible method. You are free to follow this method. You may also develop/use your own method to achieve the requested result.

You have to record parts of the process in a logbook. The log has a free format. You bundle your own notes in the logbook. The logbook serves to record your process of idea reduction, so that you can read it back later. You should preferably keep this logbook digitally as a group, for example, in the form of a blog on the internet.

Phase A

Procedure:

Step 1 (individual): Engage in multiple observations based on site visits, lectures, literature and experience, in which you identify a problem. Record these observations without thinking about possible solutions, just mention the observation and the problem! Record this in the logbook before the next step in the process (writing it down).

Step 2 (collective): Develop a design assignment from each observation. Here it is necessary that the problem definition is formulated more clearly and that consideration is given to when the problem is no longer a problem. This is not a description of a possible solution, but a description of the requirements that a good solution must meet: *user criteria.*

A good description of the problem provides a description of: 1) context - definition of limitations or deficiencies involved in the identified problem; 2) necessity - why is a solution needed, what is the need; 3). *user criteria* [1] - determine the conditions that a possible solution must meet and determine the performance that the solution must deliver.

Divide the group into two triplets. There is one questioner, one observer and one writer per each group of three. Each student performs each task at least once. With each observation from step

1, the shortcomings and limitations of the problem must be established by means of an interview with the problem owner(s) and a clear definition of the problem must be formulated.
Step 3 (collective): Discuss the problem definitions, reduce the number to a maximum of 2. You must archive the notes made, in whatever form [paper, digital (e.g., Padlet), whiteboard, etc.], in the logbook.
Step 4 (collective): Publish the research questions (max. 2) on *EducationOnline* on the project environment (link) during discussion. Start a new discussion for each problem. Provide a description of the subject of that discussion.
DEADLINE: Week 1
Step 5 (individual): Give feedback on at least 2 published problems from other groups. The feedback must be focused on the quality of the problem: did the other group share the observations and are the three requested parts (context, necessity and user criteria) correctly and / or fully described, in your opinion? You can make critical comments. *You can also name existing solutions known to you with regard to the published problem.*
DEADLINE: Week 2
Notes:
[1] The term *'user criteria'* could be translated as 'user requirements'. Terms such as 'Program of Requirements' (PVE) and 'assessment criteria' are also applicable. That is why we use the English term in this course. A '*user*' is by definition a *stakeholder*. Defining *user criteria* follows from the *stakeholder analysis*.
Generate solutions
Each group of six students is instructed to formulate a problem together. By creating knowledge (by sharing the generated problems) you can choose the best starting point for the collective (cross-group). The group must then come up with at least six innovative solutions (two radical and four incremental [1]) for the chosen problem. Use scenarios [2] to generate the solutions. Combine the solution and the user criteria and select the best solution or solution combination for the problem, based on an analytical assessment. The analytical assessment is a strategy to: identify risks, record possible returns, define decision points, identify possible uncertainties that are important, and record the data required for the course assignment.
Record intermediate steps, learning moments, reactions of group members to each other's ideas, decisions, analysis, feelings, and so forth in the logbook.

Phase B

Procedure

Step 1 (collective): Continue with one problem or choose one from the list for which an innovative solution is required. Based on the published feedback, you will critically review it again and **define** your own problem as a group.

Note: For the final advisory report, solutions have probably been requested for multiple problems. However, it is not necessary to devise an innovative solution for every problem. For the problem that you define in this problem definition, a solution must be necessary because existing solutions do not meet the user criteria.

Step 2 (individual): Consider scenarios [3] independently that will help you to arrive at different solutions as a group. Record the scenarios in the logbook before discussing them in the group.

Step 3 (collective): Organize one or more creative sessions. **A good working environment** must be **organized** to arrive at good ideas. Use your own network for this (also outside of school), organize a brainstorming session, go on an excursion to get inspiration, and so forth. Try multiple scenarios for a multitude of solution ideas [4] to come. Record the results of the sessions before the next step in the process. Archive these in the logbook.

Step 4 (collective): **Develop** a concrete solution. You do this at a different time than step 3. The solution ideas must first be structured into possible solutions by using the previously determined *user criteria.* Ensure that the ideas (2 radical and 4 incremental) are transferable by creating sketches and written explanations. Publish the results in a file (pdf, per group) on the project page on *EducationOnline.*

DEADLINE: Week 4

Step 5a (collective): Discuss the possible solutions with as many experts as possible during the PB3R theme meeting. Two groups will be invited to the workshop sessions to give a short pitch of one of their presented possible solutions. They will receive an invitation for this.

Step 5b (collective): **Analyse** the possible solutions with the entire group and select the most effective. Record the process in the logbook.

Proposal method.

Several methods are available for the analysis. In course 4, for example, you were introduced to the SWOT method. Other suitable examples are: *failure mode and effect analysis* ***(FMEA)***, *potential problem analysis* ***(PPA)***, *fault tree analysis* ***(FTA)***. Information about these analysis methods, including useful tools, is easy to find on the internet.

Notes:

[1] incremental: building on what already exists (synonyms, ascending, increasing)

[2] A scenario is a way of *thinking*. For example, for the acoustic problem of the hall there are three possible ways of thinking to come up with solutions: tackle the problem at the source (duct tape), the space (absorption) or the receiver (ear flaps).

[3] See above.

[4] Solution ideas are possible ideas, allow crazy, disruptive ideas. It is explicitly the intention not to disregard ideas during a creative session. Testing the ideas is something that should not take

place in such sessions.

Testing, implementing and developing the solution

Construction errors regularly appear in the news. This is especially the order of the day in the trade journals. Facade specialist Nico Hendriks even has a special section for this in the *Bouwwereld* Construction for Professionals journal. Recurring in his analysis is the builder/designer who did not sufficiently investigate the product's implementation beforehand, creating problems that could actually have been prevented.

Each group of six students is instructed to design a procedure for testing, simulating, modelling, prototyping, calculating, and so forth. With this procedure, the group must demonstrate the suitability of the solution. It could be that the procedure will soon prove that the solution is inappropriate. For this course, that is not the end; after all, the actual testing does not happen and often further development of the scenario that led to the solution is what is needed, only there is no opportunity for that now. A brief reflection on the entire implementation process is required during the elaboration.

Phase C

Procedure

Step 1 (collective): Bring together a network in which the group members are supplemented with experts from different fields. Create a setting where suggestions are made for testing, simulating or calculating the possible solution selected in step 5b of the previous phase. Record the suggested ideas in the logbook before the next step in the process and document the process in the logbook.

Step 2 (collective): The generated research methods must be questioned one by one on efficiency and feasibility. For efficiency, again use the *user criteria*, and make an estimate of the deployment of time and equipment for the feasibility.

Step 3 (collective): Determine a suitable test method and describe the procedure in a brief action plan (PVA). Publish the test method in a file (per group) on the project page on *EducationOnline*.

DEADLINE: Week 6

Step 4 (collective): Implement the remodelling of the house by elaborating on the advice about adjustments to make the houses energy-neutral. After all, it was all about that! You submit the report on June 14.

The innovative nature of the remodelling is assessed in the final presentations.

Step 5 (collective): Publish the logbook on the project page on *EducationOnline*.

DEADLINE: Week 8

The logbook includes a substantive report of these step: Phase A, Step 1 and Step 3; Phase B, Step 2, Step 3 and Step 5b; Phase C, Step 1.

Appendix E

Example 2 - Flooding due to excessive rainfall

This appendix presents the English translation of the Netherlands version of the task used in third study. The complete Netherlands/English versions are available from the author.

Introduction

Due to excessive rainfall in the northern province of the Netherlands, the neighbourhood of Botterdiep in the city of Groningen was flooded over. The streets of Botterdiep, which are predominantly occupied by dwellings and commercial buildings, were not accessible for pedestrians and vehicles for several days. While the Netherlands is famous and respected worldwide for their flood-fighting techniques, the inhabitants of Botterdiep to date are still experiencing flooding due to ineffective drainage, and water retention and distribution systems.
Your task is to design a way for the municipality of Groningen to combat the flooding in Botterdiep. Your solutions should focus on creating a totally new solution that solves the problem or developing totally new ways of approaching the problem.
Define the problem and develop an action plan demonstrating your systematic approach to the problem. This includes answering the following questions:
Discovery: problem analysis through observation, exploration and analysis

1. Describe the specific problem to solve (problem statement establishment).
    - Be specific in the goal and detailed in needs (i.e., what is needed to solve the problem) description.
    - Describe the importance/relevance of solving the stated problem.
    - Divide the problem into phases (sequentially and analogically).
    - Generate method(s) per phase for addressing the stated problem(s).
    - Describe the ideal situation (both scientific and practical applicability).
2. Question the question behind the given question.
    - Consider intelligibility, both scientific and practical applicability.
    - What is the context of the question?
    - Who is/are the problem owner(s) and stakeholders?
    - What intervention is needed or suggested?
    - What mechanism or device should be employed?
    - What outcome is expected or suggested?
    - Describe the specific precipitating event that caused the problem to occur.
    - Describe in general the vulnerability factors of the precipitating event.
    - Describe in exhaustive detail the events that led up to the specific problem.

3. Develop the user criteria (condition for a good solution).

Ideation: solution generation through scenario-based, divergent and convergent thinking

4. Systematically create original and appropriate solutions for the problem.

Implementation: test applicability through prototyping, testing, improving and diffusing

5. Show that your solution solves the problem.
6. Provide detailed and systematic reflection about what you learnt per innovation phase using the STARR method.

Procedure

Discovery - Step 1 (individual): Engage in multiple observations based on site visits, lectures, literature and experience, in which you identify a problem. Record these observations without thinking about possible solutions, just mention the observation and the problem! Record this in the logbook before the next step in the process (writing it down).

Discovery - Step 2 (collective): Develop a design assignment from each observation. Here it is necessary that the problem definition is formulated more clearly and that consideration is given to when the problem is no longer a problem. This is not a description of a possible solution, but a description of the requirements that a good solution must meet: user criteria.

A good description of the problem provides a description of: 1) context - definition of limitations or deficiencies involved in the identified problem; 2) necessity - why is a solution needed, what is the need; 3). user criteria determine the conditions that a possible solution must meet and determine the performance that the solution must deliver.

Appendix F

Example 3 - Unsafe traffic situation

This appendix presents the English translation of the Netherlands version of the task used in third study. The complete Netherlands/English versions are available from the author.

The traffic situation in the central station of Groningen has become overwhelming and unsafe for its users. Groningen is a major city in the northern province of the Netherlands. Its occupants are mostly civil servants and students. Every day, both the civil servants and students make use of public transportation to go their various offices or schools. The central station is a transit point for many citizens in and around Groningen. Prorail has done all it could to organize and make the traffic climate safe for its users, with very little success. The traffic situation in the central station of Groningen can be described as a danger to pedestrians, bike and vehicle users.
Your team has been commissioned to design a way for Prorail Groningen to combat the unsafe traffic situation in the central station of Groningen. Your solutions should focus on improving existing solutions or adapting familiar ways of approaching the problem or similar problems. Consider constraints such as cost, simplicity, practicality and implementation of your solution.

Appendix G

Innovation competence grading form 1

This appendix presents the English translation of the Netherlands version of the grading form used in third and fourth study. The Netherlands/English versions are available from the author.

Project Group Name: ______________________

Date: ______________________

Teacher Name: ______________________

A. The student can systematically *discover* the problem gap in each problem context after course completion (ILO 1).		0	1	2	3	N. a.	Assessed on the basis of …
1.	Understood the assignment's purpose	☐	☐	☐	☐	☐	
2.	Identified the core problem	☐	☐	☐	☐	☐	
3.	Conducted problem analysis	☐	☐	☐	☐	☐	
4.	Gathered information	☐	☐	☐	☐	☐	
5.	Conducted context analysis	☐	☐	☐	☐	☐	
6.	Defined user criteria	☐	☐	☐	☐	☐	
7.	Displayed self-management (working methodically towards targeted goal)	☐	☐	☐	☐	☐	
8.	Identified risk aspects through analysis	☐	☐	☐	☐	☐	
Result of phase A: the analytical and creative competence of the group		☐	☐	☐	☐	☐	

A

B. The student can create an original and appropriate solution to the articulated problem/question following an established creative procedure/process after course completion (ILO 2).		0	1	2	3	N. a.	Assessed on the basis of .…
9.	Thought in scenarios to generate ideas	☐	☐	☐	☐	☐	
10.	Scenario is original	☐	☐	☐	☐	☐	
11.	Scenario is appropriate	☐	☐	☐	☐	☐	
12.	Scenarios are judged based on the defined user criteria	☐	☐	☐	☐	☐	
13.	Scenarios worth pursuing are discriminated from bad scenarios (ideas)	☐	☐	☐	☐	☐	
14.	Conclusions drawn in writing	☐	☐	☐	☐	☐	
15.	Conclusions drawn verbally	☐	☐	☐	☐	☐	
16.	Reflection on the entire process.	☐	☐	☐	☐	☐	
Result of phase B: the analytical and creative competence of the group		☐	☐	☐	☐	☐	

C. The student can design and implement an experimental plan intended to demonstrate the effectiveness or shortcomings of the generated solution(s) to problems (ILO 3).		0	1	2	3	N. a.	Assessed on the basis of .…
17.	Operable implementation plan is designed	☐	☐	☐	☐	☐	
18.	Construction of prototypes, model, simulations, calculations, etc.	☐	☐	☐	☐	☐	
19.	Displays the extent of solution fitness	☐	☐	☐	☐	☐	
20.	Evaluation of the extent of solution fitness	☐	☐	☐	☐	☐	
21.	Conclusions drawn	☐	☐	☐	☐	☐	
22.	Reflection on the entire process.	☐	☐	☐	☐	☐	
Result of phase C: the analytical and creative competence of the group		☐	☐	☐	☐	☐	

A

SCORING EXPLANATION:

0 - No proof - There is no evidence in the results for this section. This may be because the item is not observed or because this is not explained in the presented results.

1 - Minimal proof - There is minimal evidence present in the results for this part or the quality of the results is low. This may be because only one or two students are involved, because a minimal

amount of time was spent, or because this is minimally explained in the presented results.

2 - Average evidence - There is sufficient evidence in the results for this part and the results shown are of sufficient quality. This is the result of the involvement of the majority of the group, there was enough time spent on it and the component is sufficiently explained in the presented results.

3 - Lots of evidence - The quality of the component is excellent and there is a lot of evidence in the presented results.

The assessment of the various components serves to objectify the final assessment; the final assessment is not an average.

Appendix H

Innovation competence grading form 2

This appendix presents the English translation of the Netherlands version of the grading form used in third and fourth study. The Netherlands/English versions are available from the author.

Project Group Name: ______________________

Date: ______________________

Teacher Name: ______________________

EXPERT FINAL JUDGEMENT

Assessment of the **degree of innovation**. To what extent has the proposed solution (product/idea/services) not been previously applied, according to the expert/teacher/person's knowledge.	Not	Probably not	Probably	Is	Cannot be ascertained
The proposed solution (product / idea / service), based on the knowledge of the expert involved, is or is not innovative.	☐	☐	☐	☐	☐
Brief justification:					

Assessment of the degree of implementation /applicability. To what extent is the proposed solution (product/idea/services) able to be implemented/applicable, according to the expert/teacher/person's knowledge.	Not possible	Low	Moderate	High	Very high
Based on the knowledge of the expert involved, the potential of the proposed solution (product / idea / service) to be implemented is:	☐	☐	☐	☐	☐
Brief justification:					

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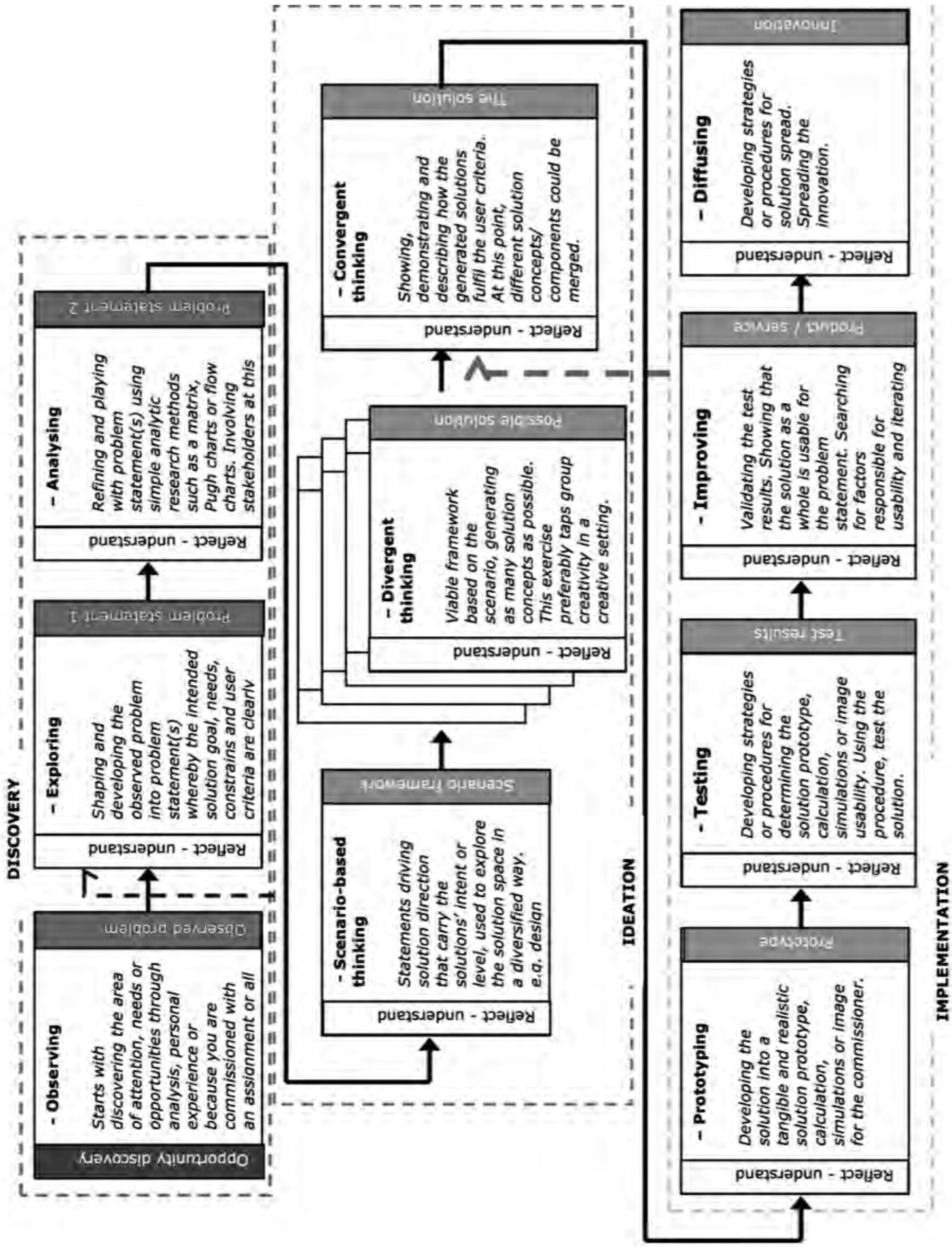
Appendix I

Innovation process, teaching procedure and content

This appendix presents the English translation of the Netherlands version of the teaching procedure and content used in third and fourth study. The complete Netherlands/English versions are available from the author.



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Appendix J

Mean student scores for pre-test/post-test survey per rubric item

This appendix presents the English translation of the Netherlands version of the survey used in fourth study. The Netherlands/English versions are available from the author.

Survey item	**Pre-test**		**Post-test**	
Pre: Based on regular lessons, I learned to....... **Post: Based on the innovation competence instruction of year 4, I learned to ....**	**M**	**SD**	**M**	**SD**
1. Resolve every complex problem I face systematically.	2.41	1.07	5.04	1.25
2. Conduct context analyses systematically.	2.65	1.10	4.90	1.10
3. Have confidence in tackling complex problems creatively.	2.50	1.03	3.85	1.48
4. Conduct risk analyses.	2.61	1.04	5.04	1.12
5. Formulate the tasks that are to be undertaken for situation improvement.	2.20	0.93	5.15	1.30
6. Research the question behind the question.	2.28	1.09	5.44	.98
7. Generate innovative ideas through creative thinking.	2.24	1.24	5.02	1.22
8. Reflect on the process of solution generation.	2.17	0.88	5.13	1.13

This item used a 7-point response scale, where 7 = strongly agree and 1 = strongly disagree. N = 46.

A

Appendix K

Focus group discussion guiding questions

This appendix presents the English translation of the Netherlands version of the question form used in the fourth study. The Netherlands/English versions are available from the author.

1. What do you think of the innovation training?
2. What did the innovation training contribute to your innovation competence learning?
3. What do you think of the description of the assignment in the innovation training?
4. Was it possible to formulate a good description of the problem using the procedure provided?
5. Did you succeed in coming up with useful solution ideas using the procedures described in the tasks?
6. How would you rate the individual task descriptions?
7. Did the training aid or hinder your innovation competence learning?
8. Do you feel that this training on innovation competence has made you more innovative?
9. Can you transfer the insights gained from the innovation module to other assignments?

Appendix L

Mean average scores for students' innovation competence deliverables per rubric item

This appendix presents the English translation of the Netherlands version of the grading form used in the fourth study. The Netherlands/English versions are available from the author.

Rubric Item	M	SD
1. Understood the assignment's purpose	3.54	.751
2. Identified the core problem	3.52	.781
3. Conducted problem analysis	3.52	.781
4. Gathered information	3.43	.688
5. Conducted context analysis	3.43	.834
6. Defined user criteria	3.39	.774
7. Displayed self-management (working methodically towards targeted goal)	3.61	.714
8. Identified risk aspects through analysis	3.46	.780
9. Thought in scenarios to generate ideas	3.41	.686
10. Original scenario	3.50	.753
11. Appropriate scenario	3.46	.751
12. Judged scenarios based on the defined user criteria	3.52	.722
13. Discriminated scenarios worth pursuing from bad scenarios (ideas)	3.37	.826
14. Drew conclusions in writing	3.46	.690
15. Drew conclusions verbally	3.30	.628
16. Reflected on the discovery and creativity processes	3.15	.788
17. Designed operable implementation plan	3.33	.701
18. Constructed prototypes, model, simulations, calculations, and so forth	3.37	.679
19. Displayed the extent of solution fitness	3.33	.560
20. Evaluated the extent of solution fitness	3.43	.620
21. Drew conclusions	3.37	.645
22. Reflected on the entire process (discovery, creativity, implementation)	3.35	.674

Grade score scale: 1 = bad; 2 = poor; 3 = satisfactory; 4 = good; 5 = excellent. N = 46.

Nederlandse Samenvatting

Introductie

Het ontwikkelen van de innovatiecompetentie van studenten wordt door zowel wetenschappers als onderwijsbeleidsadviseurs als relevant beschouwd. Tegenwoordig zijn innovatieve professionals meer dan ooit nodig. Er wordt verwacht dat het hoger onderwijs afgestudeerden aflevert met de competentie om te innoveren, zodat ze goed kunnen functioneren in steeds veranderende werkomgevingen. Helaas laat onderzoek uit het buitenland zien dat het hoger onderwijs in het algemeen nog beperkt er in slaagt om innovatiekracht bij studenten te ontwikkelen en hen voor te bereiden op de uitdagingen van de 21ste eeuw. Het hoger onderwijs zou zich meer moeten richten op het ontwikkelen van de innovatiecompetentie van studenten, zodat zij voldoen aan organisatorische en maatschappelijke eisen. Als gevolg van de beperkte focus op de innovatiecompetentie van studenten in het hoger onderwijs, is meer onderzoek nodig om factoren en manieren in het onderwijs te identificeren die de innovatiecompetentie bij studenten bevorderen.

In Nederland erkent de Vereniging van Hogescholen (VH) de noodzaak om ervoor te zorgen dat afgestudeerden de innovatiecompetentie verwerven die vereist is op de (toekomstige) arbeidsmarkt en benadrukte in 2015 de noodzaak om de innovatiecompetentie van studenten in het bouwkundig domein expliciet te ontwikkelen. Sinds 2015 streven veel Bouwkunde opleidingen ernaar om de innovatiecompetentie expliciet te onderwijzen. Hoewel de VH het belang van de ontwikkeling van de innovatiecompetentie van studenten benadrukte, gaf zij niet aan hoe opleidingen deze competentie in het curriculum konden opnemen. Ook werd deze innovatiecompetentie niet verder toegelicht en werd niet beschreven welke leeractiviteiten docenten zouden kunnen organiseren of hoe deze competentie beoordeeld kon worden. De innovatiecompetentie bestaat uit complexe vaardigheden, kennis en attitudes die met elkaar samenhangen. Veel literatuur op dit vlak richt zich vooral op creativiteit als persoonlijkheidskenmerk. Doorgaans beschrijft beleid vaak niet expliciet wat de innovatiecompetentie is, waardoor er (te) veel ruimte is voor individuele interpretaties, wat tot verwarring leidt bij opleidingen. Kaders voor leer- en onderwijsactiviteiten om innovatiecompetentie te bevorderen zijn beperkt beschikbaar.

Op dit moment is echter niet bekend of de huidige curricula in het hoger onderwijs inderdaad gericht zijn op de ontwikkeling van de innovatiecompetentie en zo ja, in welke mate. Een manier om hier achter te komen, is door de opvattingen en percepties van docenten en studenten over de innovatieondersteunende leeromgeving in kaart te brengen. Aangezien opvattingen over leeromgevingen doorgaans verschillen, is het de vraag in hoeverre de opvattingen van docenten en studenten over innovatieondersteunende leeromgevingen overeenkomen en of de huidige leeromgeving inderdaad voldoende ondersteuning biedt voor het ontwikkelen van de innovatiecompetentie.

Innovatiecompetentie wordt in dit proefschrift gedefinieerd als de competentie om systematisch tekortkomingen in een context/situatie te ontdekken en innovatieve vragen op te stellen, creatieve ideeën voor producten, diensten, procedures en theorieën te genereren, het nut of de betekenis van een oplossing aan te tonen via reflectie en aan te tonen dat de gegenereerde oplossingen succesvol kunnen worden geïmplementeerd.

Doelstellingen, positionering en structuur

Het doel van dit proefschrift is:

1. in hoeverre de bestaande curricula in het Bouwkunde onderwijs de ontwikkeling van de innovatiecompetentie ondersteunen, en
2. hoe de innovatiecompetentie in deze opleidingen kan worden bevorderd.

Door onderzoek te doen naar de opvattingen van belanghebbende studenten en docenten over de mate waarin hun bestaande curricula gericht zijn op onderwijs op het gebied van de innovatiecompetentie, kan beter worden begrepen hoe effectieve principes kunnen worden ontwikkeld voor het ontwerp van onderwijs dat de innovatiecompetentie ondersteunt. Het onderzoek in dit proefschrift is gepositioneerd binnen breder onderzoek naar leeromgevingen in het hoger onderwijs. Het bestaat uit vier onderzoeken, waarbij gebruik gemaakt is van verschillende onderzoeksmethoden, die een aanpak voor ontwerpgericht onderwijsonderzoek volgen.

Dit proefschrift bestaat uit twee delen. Het eerste deel is een behoeften- en contextanalyse (waarbij hoofdstuk 2 focust op studenten en hoofdstuk 3 focust op docenten), uitgevoerd op acht Nederlandse hogescholen waar de innovatiecompetentie onderdeel uitmaakte van het afstudeeronderzoek van Bouwkunde studenten. Het tweede deel bevat het ontwerp en de uitvoering van een interventie (hoofdstukken 4 en 5) geïmplementeerd binnen het bestaande Bouwkunde curriculum van drie Nederlandse hogescholen waarin het ontwikkelen van de innovatiecompetentie van studenten een leerdoel was. De volgende paragraaf geeft een overzicht van de theoretische concepten en onderzoeksvragen.

Onderzoekscontext, gegevens en methoden

In dit proefschrift is ontwerpgericht onderwijsonderzoek als overkoepelende aanpak gebruikt. De vier onderzoeken benaderden de innovatiecompetentie vanuit verschillende perspectieven, waarbij de onderzoeksdeelnemers, de onderzoeksmethoden en de gegevensverzameling verschilden. In Nederland hebben hogescholen de autonomie om hun eigen pedagogische onderwijsbenadering te kiezen, waardoor het ontwikkelen van de innovatiecompetentie per hogeschool anders kan worden benaderd. Gegevens voor alle onderzoeken zijn verzameld tussen 2016 en 2019. Het eerste onderzoek was gebaseerd op kwantitatieve gegevens van 130 studenten voor wat betreft hun zelfinschatting van hun innovatiecompetentie en hun perceptie van de mate waarin de bestaande leeromgeving waarin ze zich bevonden gericht was op de innovatiecompetentie, verzameld via een geconstrueerde vragenlijst. Het tweede onderzoek was gebaseerd op kwantitatieve gegevens van 94 docenten voor wat betreft hun eigen creatieve self-efficacy, hun opvattingen over de relevantie van de innovatiecompetentie en hun perceptie van de mate waarin de bestaande leeromgeving gericht was op de innovatiecompetentie, eveneens via een vragenlijst. De resultaten van docenten en studenten zijn ook onderling vergeleken. Het derde onderzoek ging in op theoretische ontwerpprincipes die de basis vormden voor een onderwijsprototype. Het vierde en laatste onderzoek was een evaluatiestudie. Dit deelonderzoek onderzocht de effectiviteit van het innovatiecompetentie-prototype op een van de hogescholen en tijdens de ontwikkeling ervan werden eerdere iteraties elk getest op een andere hogeschool. Het evaluatieonderzoek bestond uit:

1. een pre- en posttest van de zelf ervaren innovatiecompetentie met 46 deelnemende studenten,
2. semigestructureerde interviews met een subgroep van 18 studenten,
3. semigestructureerde interviews met 2 docenten
4. een analyse van producten van 46 studenten beoordeeld door 12 docenten.

In totaal bestond het proefschrift dus uit drie fasen. In de fase van behoefte- en contextanalyse zijn twee onderzoeken uitgevoerd in het Bouwkunde domein op acht hogescholen. De ontwerp- en bouwfase is beschreven in één onderzoek. De implementatie- en evaluatiefase omvatte eerst drie iteraties, waarbij elke iteratie plaatsvond op een andere hogeschool. Na deze iteraties is de resulterende interventie geëvalueerd in een vierde iteratie aan weer een andere hogeschool.

Doelen en belangrijkste bevindingen

Om de doelen te bereiken zijn in de inleiding van dit proefschrift vier onderzoeksvragen onderzocht:

1. In welke mate ervaren Bouwkunde studenten aan hogescholen de bestaande leeromgeving als ondersteunend voor het ontwikkelen van hun innovatiecompetentie, hoe ervaren studenten

hun eigen innovatiecompetentie en wat is hun perceptie van de leeromgeving?
2. In welke mate beschouwen Bouwkunde docenten aan hogescholen hun leeromgeving als ondersteunend voor het ontwikkelen van de innovatiecompetentie bij studenten, welke opvattingen hebben zij over het innovatiecompetentieonderwijs en hoe beïnvloeden deze overtuigingen en percepties elkaar?
3. Op welke ontwerpprincipes kan het innovatiecompetentie onderwijs worden gebaseerd en hoe kan de interventie met succes in de praktijk worden geïmplementeerd?
4. In hoeverre is de interventie, gebaseerd op de ontwerpprincipes voor innovatiecompetentieonderwijs, effectief in het vergroten van de innovatiecompetentie van studenten?

Hoofdstuk 2 bracht de percepties van studenten van de leeromgeving met betrekking tot de ontwikkeling van de innovatiecompetentie en het zelf ervaren niveau van de innovatiecompetentie van studenten in kaart. Ook werden de percepties van studenten van de focus op en de relevantie van de innovatiecompetentie in het curriculum van hun opleiding in kaart gebracht, evenals de relatie tussen de leeromgevingn en het zelf ervaren niveau van de innovatiecompetentie. Er zijn gegevens verzameld bij 130 Bouwkunde studenten aan acht hogescholen in Nederland. Een factoranalyse als de betrouwbaarheidsanalyse lieten bevredigende resultaten zien voor het meten van de verschillende variabelen.

De resultaten toonden aan dat studenten hun motivatieniveau, creativiteit en geloof in eigen creatieve kunnen iets hoger vonden dan hun vermogen om onduidelijke problemen op te lossen, hun neiging tot risico's nemen en hun zelf ervaren leiderschap. Bovendien beschouwden de studenten hun leeromgeving gemiddeld als matig innovatiegericht, aangezien alle scores rond het middelpunt lagen, waarbij aandacht voor persoonlijke relevantie als laagste werd beoordeeld, het ruimte bieden voor onderhandeling door studenten als hoogste en rekening houden met onzekerheid uitkwam tussen deze twee scores. De scores van studenten van de focus op de innovatiecompetentie op school-/curriculumniveau lieten een matige focus op de innovatiecompetentie zien. Ten aanzien van de vraag of het ontwikkelen van de innovatiecompetentie door studenten relevant is, gaven studenten aan dat ze dit enigszins relevant vonden. Er werden zeven stapsgewijze, meervoudige regressieanalyses uitgevoerd om de gezamenlijke en unieke voorspellende bijdrage van de leeromgeving, focus- en relevantievariabelen aan de totale innovatiecompetentie van studenten en de individuele componenten ervan te bepalen. Deze regressieanalyses lieten zien dat de percepties van studenten over persoonlijke relevantie positief gerelateerd waren aan hun zelf ervaren leiderschap, energie en vermogen om complexe problemen op te lossen. Percepties van ruimte voor onderhandeling waren positief gerelateerd aan creativiteit, geloof in eigen creatieve kunnen en de algemeen ervaren innovatiecompetentie. De waargenomen focus in het curriculum op innovatie was positief gerelateerd aan zelf ervaren risicobereidheid. In alle gevallen was de mate van verklaarde relevantie met ongeveer 5% relatief klein. Toch waren alle gevonden verbanden statistisch significant. De resultaten lieten zien dat hogescholen explicieter en structureler zouden moeten focussen op het onderwijzen en beoordelen van de innovatiecompetentie. Deze resultaten suggereerden dat studenten de bestaande leeromgevingen als minder ondersteunend beschouwden dan gehoopt en toonden de noodzaak aan om de leeromgevingenprincipes explicieter te implementeren. Volgens de mening van de studenten waren de docenten in hun opleiding (nog) niet sterk gericht op innovatiecompetentieonderwijs.

Op basis van de conclusie van het eerste onderzoek, zoals gepresenteerd in hoofdstuk 2, hadden docenten, volgens de mening van studenten, in hun onderwijs geen expliciete focus op innovatiecompetentieonderwijs. Uit eerder onderzoek naar leeromgevingen in verschillende onderwijsdomeinen is gebleken dat er aanzienlijke verschillen bestaan tussen de percepties van docenten en studenten. In deze onderzoeken waren de percepties van studenten doorgaans minder positief dan die van docenten. In het tweede deelonderzoek in hoofdstuk 3 onderzochten we de opvattingen van docenten over de relevantie van de innovatiecompetentie, hun geloof in de eigen creatieve kunnen en vergeleken we de percepties van docenten en studenten over de leeromgeving. We hebben ook de perceptie van docenten over de focus op de innovatiecompetentie op hogeschool-/curriculumniveau in kaart gebracht, evenals de samenhang tussen de leeromgevingen en de creatieve self-efficcy, de focus op het onderwijzen van de innovatiecompetentie en de relevantie van het lesgeven op het gebied van de innovatiecompetentie. Gegevens zijn verzameld bij 94 Bouwkunde docenten van acht hogescholen in Nederland. Factoranalyses en betrouwbaarheidsanalyses lieten bevredigende resultaten zien voor alle constructen. De resultaten lieten gemiddeld neutrale waarnemingen zien voor de focus op het innovatiecompetentieonderwijs. Er werd echter een relatief grote variatie in scores gevonden. Docenten waren niet eensluidend overtuigd over de relevantie van de innovatiecompetentie. Een aantal docenten vond innovatiecompetentieonderwijs zeer relevant, terwijl sommigen zelfs negatief waren over de relevantie ervan. Dit is een opmerkelijke bevinding, gezien de relevantie van de innovatiecompetentie voor de samenleving en economie. De resultaten toonden aan dat docenten vertrouwen hadden in hun creatieve self-efficacy. In dit hoofdstuk is ook gezocht naar verschillen in perceptie tussen studenten en docenten over hun leeromgeving. Docenten scoorden op alle variabelen duidelijk hoger dan studenten. Statistisch significante verschillen in percepties werden gevonden voor de variabelen in de leeromgeving: aandacht voor persoonlijke relevantie, rekening houden met onzekerheid en ruimte bieden voor onderhandeling door studenten. De bevindingen komen overeen met eerdere onderzoeken waarin de percepties van studenten en docenten werden vergeleken.

Er werden vier stapsgewijze, meervoudige regressieanalyses uitgevoerd om de gezamenlijke en unieke relaties tussen elk van de leeromgevingsschalen, de docentgerelateerde overtuigingen en de opvattingen van docenten over de focus op de innovatiecompetentie op curriculumniveau te bepalen. Deze regressieanalyses gaven aan dat de relevantie van innovatie een significante en positieve focus op de innovatiecompetentie voorspelde. Focus op de innovatiecompetentie op curriculumniveau voorspelde significant en positief rekening houden met onzekerheid. Creatieve self-efficact voorspelde significant de waargenmen ruimte voor onderhandeling door studenten. In alle gevallen was sprake van een verklaarde variantie tussen 6 en 11%, wat relatief beperkt was. Toch waren alle gevonden verbanden statistisch significant.

Ontwerpgericht onderwijsonderzoek pleit voor de ontwikkeling van een reeks ontwerpprincipes die zijn gebaseerd op bestaande empirische analyses en theoretische principes. Deze principes worden gebruikt om het ontwerp en de ontwikkeling van leeromgevingen en een interventie voor de innovatiecompetentie te ondersteunen. Het doel van de voorgestelde ontwerpprincipes is niet om een reeks verplichte procedures en processen te creëren die docenten kunnen implementeren, maar eerder om de kloof tussen onderwijsbeleid en -praktijk te overbruggen. Deze kloof houdt verband met het feit dat innovatiecompetentieondersteunend leren in het Bouwkunde domein nog niet expliociet gericht is op innovatiecompetentie, zoals bleek uit de uitgevoerde behoeften- en contextanalyse (hoofdstuk 2 en 3). Zelfbeoordelingen van studenten lieten zien dat de bestaande leeromgevingen onvoldoende de innovatiecompetentie van studenten in de praktijk bevorderden. Ook verschilden studenten en docenten van mening over het waargenomen innovatiecompetentieonderwijs en de meeste docenten vonden de innovatiecompetentie beperkt relevant. De ontwerpprincipes en de vertalingen ervan kunnen dienen als voorbeeldmaterialen en bouwstenen voor degenen die op zoek zijn naar inspirerende richtlijnen voor het ontwikkelen van de innovatiecompetentie in hun praktijk. Het is aangetoond dat het bieden van professionele ondersteuning aan studenten een effectieve manier is om de innovatiecompetentie van studenten te ontwikkelen. Deze resultaten van de behoeften- en contextanalyse (hoofdstuk 2 en 3) toonden de noodzaak aan van een interventie die vooral gericht is op het aanleren van de innovatiecompetentie via een expliciete benadering van innovatiecompetentieonderwijs. Op basis van de literatuur en de bevindingen van de eerste twee onderzoeken zijn zes ontwerpprincipes geformuleerd voor het ontwerp van een innovatiecompetentieondersteunende interventie. De zes ontwerpprincipes die in hoofdstuk 4 worden voorgesteld, zijn tot stand gekomen uit verschillende theoretische principes, praktische inzichten en aanbevelingen. Het viercomponenten instructieontwerpmodel voor complexe competenties ofwel het 4C/ID-model, constructive alignment, het vereenvoudigde innovatieproces en constructivisme vormden de belangrijkste theoretische basis voor de zes ontwerpprincipes. De zes principes zijn:

1. Definieer holistische maar meetbare leerdoelen;
2. Neem constructivistische leerprincipes op in de leeromgeving;
3. Baseer het onderwijs op de volgorde van het innovatieproces;
4. Leer studenten gedegen creatieve technieken;
5. Zorg ervoor dat beoordelingen van innovatiecompetentie eenvoudig te gebruiken zijn, systematisch, in overeenstemming zijn met de leeractiviteiten en beknopt maar alomvattend genoeg zijn om relevante aspecten van innovatiecompetentie vast te leggen;
6. Richt beoordelingen van de leerresultaten van studenten meer op het proces dan op het product.

De zes ontwerpprincipes zijn gerangschikt volgens de drie aspecten van constructive alignment, namelijk doelen, onderwijs-leeractiviteiten en beoordelingen. De doelen beschreven de beoogde leerresultaten, terwijl de les- en leeractiviteiten een procedure aangeven. Ten slotte beschrijft het assessment het wat en hoe van de innovatiecompetentie-beoordelingen. De doelen, activiteiten en beoordelingen omvatten de drie fasen van het innovatieproces: probleemopsporing, creatieve oplossingsideeën genereren en oplossingsimplementatie.

Deze ontwerpprincipes waren de basis voor de ontwikkeling van het instructieprototype voor de innovatiecompetentie, dat in het volgende hoofdstuk werd geëvalueerd en getest. Het betrof een fundamenteel andere benadering van lesgeven en leren, waarbij leeractiviteiten die bedoeld waren om de innovatiecompetentie bij studenten te bevorderen, werden georkestreerd. Studenten werd gevraagd om innovatieve problemen te identificeren en innovatieve oplossingen te ontwikkelen voor taken in het Bouwkunde domein. Enkele voorbeelden van taakscenario's waren het energieneutraal maken van woningen, het ontwikkelen van mechanismen en interventies om overstromingen in overstromingsgevoelige regio's te beperken en het identificeren van innovatieve problemen en het ontwikkelen van innovatieve oplossingen voor de verkeersveiligheid in centrale transportstations. De duur van de taken varieerde van 2 tot 8 weken, afhankelijk van het studiejaar en de taakfocus.

Hoofdstuk 5 was gericht op het testen van de effectiviteit van de innovatiecompetentie-interventie beschreven in hoofdstuk 4. De interventie kwam tot stand via verschillende iteraties bij Bouwkunde opleidingen van drie verschillende hogescholen. Het interventieonderzoek maakte deel uit van een cursus innovatiecompetentie (15 ECTS) en werd uitgevoerd volgens een mixedmethode-benadering met laatstejaars studenten van een van de deelnemende hogescholen. Er zijn verschillende gegevens verzameld. Ten eerste moesten studenten een pre- en posttest vragenlijst invullen waarin werd gevraagd naar hun eigen waargenomen innovatiecompetentie. T-tests met gepaarde steekproeven zijn uitgevoerd om de pre- en posttestscores van studenten te vergelijken. De stijging van de scores van studenten voor alle drie de beoogde leerresultaten was statistisch significant: studenten waren het er redelijk over eens dat ze hadden geleerd innovatieve vragen te stellen, creatieve oplossingen voor het opgeworpen probleem te bedenken en te laten zien dat de ontwikkelde oplossing voor het probleem geschikt was, terwijl zij het er voorafgaand aan het onderzoek minder vaak met elkaar over eens waren. Verbetering van de scores voor een overkoepelend, gecombineerde competentie was ook statistisch significant. Er was sprake van een groot effect.

Ten tweede werden de eindproducten van de studenten beoordeeld via rubrieken. Zes duo's van docenten gebruikten een rubric met 22 items om gezamenlijk de producten van 46 studenten te beoordelen. Uit de beoordeling van de eindproducten van studenten door deze docentbeoordelaars aan het einde van het semester bleek dat de meerderheid van de 43 studenten een cijfer boven de 3 behaalde op een schaal van 1 (laagste) tot 5 (hoogste). De beoordelaars beoordeelden het merendeel van de resultaten van de studenten als bevredigend. Het werk van één student werd als slecht beschouwd en het werk van twee studenten werd door hun beoordelaars als uitstekend beschouwd.

Ten derde werden er groepsinterviews gehouden aan het einde van de laatste cursusdag met belanghebbende studenten en docenten. Het groepsinterview was bedoeld om inzicht te krijgen in de meningen van studenten en docenten over het ontwerp en de inhoud van de cursus. Drie groepen studenten werden uitgenodigd om deel te nemen aan de groepsdiscussie. Ook een aantal docenten werden geïnterviewd over de innovatieve aard van het werk van de studenten. De gegevens van studenten werden gegroepeerd door uitspraken te koppelen aan de ontwerpprincipes, terwijl de gegevens van docenten werden gegroepeerd door uitspraken te verbinden met de drie leerdoelen. Over het algemeen was de meerderheid van de docenten die het werk van studenten beoordeelden, tevreden over de methodische aanpak van studenten bij het identificeren van problemen en het genereren van oplossingen. Docenten waren tevreden over de producten van de studenten, vooral wanneer de klant de oplossing nuttig vond. Het reflectievermogen van studenten was ook een aspect dat docenten meenamen bij het bepalen van de cijfers van studenten. De resultaten van het interview toonden aan dat de interventie op het gebied van de innovatiecompetentie het inzicht van studenten in het innovatieproces vanuit het perspectief van de studenten bevorderde. De resultaten van verschillende groepsinterviews waren volledig consistent en complementeerden het beeld dat werd weergegeven uit de pre- en post vragenlijst. De studenten begrepen de stappen en procedures in de taken om een innovatieve vraag te bedenken, de creativiteit en de implementatiesessies. Studenten waren ervan overtuigd dat de procedures geen belemmering vormden voor hun vermogen om creatief te denken of innovatieve ideeën te genereren. Studenten gaven ook aan vertrouwen te hebben in de transfereerbaarheid van de opgedane kennis van de opleiding naar andere vakgebieden. Over het algemeen droegen de analyse van zowel de zelfbeoordeling door studenten als de productbeoordelingsgegevens van studenten positief bij aan de zes ontwerpprincipes voor innovatiecompetentieonderwijs. Geconcludeerd kan worden dat, door zorgvuldig en weloverwogen rekening te houden met belangrijke ontwerpprincipes voor onderwijs van innovatiecompetentie, het mogelijk was om een adequate en bruikbare instructie-interventie te ontwerpen om de innovatiecompetentie van studenten te bevorderen.

Wetenschappelijke beperkingen en suggesties voor toekomstig onderzoek

Dit proefschrift heeft aangetoond dat de innovatiecompetentie van studenten kan worden verbeterd via een expliciete en gestructureerde aanpak. Niettemin heeft dit proefschrift, naast de antwoorden, enkele gevolgen voor toekomstig onderzoek naar innovatiecompetentie¬ondersteunende instructie- en leeromgevingen. Ten eerste, deze interventie is uitgevoerd in een onderwijsdomein en aan een hogeschool; het implementeren van de interventie in andere onderwijsdomeinen en bij andere hogescholen zal nuttige kennis opleveren over de brede implementatie en validiteit van de interventieprincipes. Ten tweede, overtuigingen over de relevantie van de innovatiecompetentie moeten ook kwalitatief worden onderzocht om een meer diepgaand inzicht te krijgen in de relevantie die een docent hecht aan de innovatiecompetentie. Ten derde, het onderzoek richtte zich alleen op de percepties van docenten en studenten. Bij toekomstige onderzoeken kunnen ook andere medewerkers van de onderwijsorganisatie worden betrokken, zoals directeuren, teamleiders en curriculumcommissies, en andere organisatieniveaus, zoals hoger, midden- en lager management en stafafdelingen. Ten slotte, de interventie werd gekenmerkt door een grote rol en actieve betrokkenheid van de onderzoeker tijdens de meeste onderzoeksfasen. Toekomstige onderzoeken kunnen ernaar streven de effectieve balans te onderzoeken tussen de acties van experts en onderzoekers en de actieve betrokkenheid bij docenten die nodig is om de innovatiecompetentie goed te implementeren.

Praktische implicaties

Ons onderzoek draagt bij aan verschillende uitgangspunten voor het stimuleren van de ontwikkeling van de innovatiecompetentie van studenten in hogeronderwijsinstellingen zoals hogescholen.

Ten eerste, het onderzoek gebruikte zes kenmerken van innovatieve professionals: creativiteit, leiderschap, creatieve zelfredzaamheid, energie, risicogerichtheid en complexe probleemoplossing); en drie onderling verbonden processen, namelijk innovatieve probleemopsporing, generatie van creatieve oplossingsideeën en implementatie van oplossingen. Daarom kan onze onderverdeling van de innovatiecompetentie worden gezien en gebruikt als een format voor het ontwerp en de afstemming van het aanleren van de innovatiecompetentie. Ten tweede, het onderzoek genereerde handige vragenlijsten en tools om te bepalen in hoeverre de leeromgeving de innovatiecompetentie ondersteunt, de perceptie van studenten van hun eigen innovatiecompetentie en de diverse overtuigingen van docenten op het gebied van de innovatiecompetentie. De enquête kan worden gebruikt om onderwijsinteresse op te sporen en te richten op de innovatiecompetentie door probleemgebieden te verklaren en te identificeren. Ten derde, dit onderzoek heeft concrete voorbeelden opgeleverd van lesmateriaal en tools in de vorm van rubrieken voor het beoordelen van de innovatiecompetentie. Docenten kunnen bijvoorbeeld de beoordelingsrubrieken gebruiken om de ontwikkeling van de innovatiecompetentie van studenten door de opleiding heen te meten en om de effectiviteit van hun eigen onderwijsinterventie te meten. Ten vierde, dit proefschriftonderzoek leverde zes bruikbare ontwerpcriteria op voor het ontwikkelen van leeromgevingen die de innovatiecompetentie ondersteunen in de context van het hoger onderwijs. Deze principes kunnen in de praktijk worden gebruikt als checklist of onderbouwing.

Concluderende opmerkingen

Concluderend blijkt dat uit het onderzoek in dit proefschrift dat de innovatiecompetentie van studenten positief beïnvloed kan worden door training. De bevindingen van dit onderzoek suggereerden dat de innovatiecompetentietraining van studenten plaatsvindt door expliciet op elkaar afgestemde leer- en onderwijsactiviteiten, ontwerp, beoordeling en reflectie. Het bleek dat deze innovatieondersteunende leeromgeving de daadwerkelijke innovatiecompetenties van studenten beïnvloedde en dat de onderwijsuitvoering (met name een beter gestructureerde, evenwichtige en meer studentgerichte constructivistische benadering van lesgeven) een positieve invloed had op het leren van de innovatiecompetentie door studenten. Uit dit proefschrift is gebleken dat elke student het potentieel heeft om innovatief te zijn; dat docenten hun rol kunnen vervullen door het innovatiepotentieel van studenten te erkennen door een onderwijs- en leeromgeving te creëren die de innovatiecompetentie bevordert en aanmoedigt. Het is onze oprechte hoop dat deze onderzoekslijn doorgezet wordt, in samenwerking met onderzoekers en docenten uit verschillende vakgebieden, om gezamenlijk te onderzoeken hoe de innovatiecompetentie kan worden bevorderd via expliciet onderwijs, zodat alle studenten kunnen profiteren van het ontwikkelen van de innovatiecompetentie.

English Summary

Introduction

Developing students' innovation competence is considered relevant by both academics and educational policy advisors. Today, innovative professionals are needed more than ever. Higher education is expected to equip graduates with the competence to innovate so that they can function well in ever-changing work environments. Unfortunately, international research shows that higher education in general still has limited success in developing innovative power among students and preparing them for the challenges of the 21st century. Higher education thus should focus more on developing students' innovation competence so that they meet organizational and societal demands. Due to the limited focus on students' innovation competence in higher education, more research is needed to identify factors and educational methods that promote innovation competence.

The Netherlands Association of Universities of Applied Sciences (Vereniging van Hogescholen; VH) recognizes the need to ensure that graduates acquire the innovation competence required in the (future) labour market. In 2015, the VH emphasized the need to explicitly develop students' innovation competence in the domain of Built Environments, and since then, many Built Environments courses or programmes have strived to explicitly teach innovation competence. Although the VH emphasized the importance of developing students' innovation competence, it did not indicate how programs could incorporate this competence into the curriculum. Furthermore, this innovation competence was not further defined or described, and what learning activities teachers could organize or how this competence could be assessed was not described either. Innovation competence consists of complex skills, knowledge and attitudes that are related to each other. Much literature in this area mainly focused on creativity as a personality trait. In general, policy documents often do not explicitly describe what innovation competence is, leaving (too) much room for individual interpretation, which leads to confusion in study programmes and with the teachers involved. Frameworks for learning and teaching activities to promote innovation competence are limited.

Innovation competence is defined in this thesis as the competence to systematically discover shortcomings in a context/situation, to formulate innovative questions, generate creative ideas for products, services, procedures and theories, to demonstrate the usefulness or significance of a solution through reflection and to demonstrate that the generated solutions can be successfully implemented.

It is at present unknown whether current curricula in higher education indeed aim at developing innovation competence and, if so, to what extent. One way to find out is by mapping the views and perceptions of teachers and students about their learning environments as innovation-supportive. Since views on learning environments generally differ, the extent to which the views of teachers and students about their learning environments as innovation-supporting correspond and whether their current learning environment indeed offers sufficient support for the development of innovation competence are issues open to question.

Objectives, positioning and structure

The aim of this thesis is to investigate:

1. to what extent the existing curricula in Built Environments education support the development of innovation competence, and
2. how innovation competence can be promoted in these courses.

By considering the views of interested students and educators about the extent to which their existing curricula focuses on innovation competence education, better understanding of how to develop effective principles for designing education that supports innovation competence is possible. The research in this thesis is positioned within broader research into learning environments in higher education. It consists of four studies, using different research methods, which follow a design-oriented educational research approach.

This dissertation consists of two parts. The first part is a needs and context analysis (in which chapter 2 focuses on students and chapter 3 focuses on teachers) conducted at eight Dutch universities of applied sciences in which innovation competence was part of Built Environments students' graduation project. The second part presents the design and implementation of an intervention (chapters 4 and 5) implemented within the existing Built Environments curriculum of three Dutch universities of applied sciences in which the development of students' innovation competence was a learning objective. The next section provides an overview of the overall research approach and research questions.

S

Research context, data and methods

Design-oriented educational research was used as the overarching approach in this dissertation. The four studies approached innovation competence from different perspectives, with different study participants, research methods and data collection. In the Netherlands, universities of applied sciences have the autonomy to choose their own pedagogical approach, which means that the development of innovation competence can be approached differently per university.

In the first study, quantitative data were collected regarding students' self-perceived innovation competence and their perception of the extent to which their existing learning environment was focused on innovation competence, using a constructed questionnaire. In the second study, quantitative data were collected from teachers regarding their own creative self-efficacy, their views on the relevance of innovation competence and their perception of the extent to which the existing learning environment was focused on innovation competence, also via a questionnaire. The results of teachers and students were also compared. The third study explored theoretical design principles that formed the basis for an educational prototype. The fourth and final study was an evaluation study, which investigated the effectiveness of the innovation competence prototype at one of the universities; during its development, previous iterations were each tested at a different university. Using a mixed method approach, quantitative and qualitative data were collected through pre- and post-tests of students' self-perceived innovation competence, semi-structured interviews with a subgroup of students, semi-structured interviews with teachers, and an analysis of students' products as assessed by teachers.

Goals and key findings

In order to achieve the goals of this dissertation, four research questions were formulated in the introduction to this thesis:

1. To what extent do Built Environments students at universities of applied sciences experience the existing learning environment as supportive for the development of their innovation competence, how do students experience their own innovation competence and what is their perception of the learning environment?
2. To what extent do Built Environments teachers at universities of applied sciences regard their learning environment as supportive for the development of innovation competence in students, what views do they have about innovation competence education and how do these beliefs and perceptions influence each other?
3. On what design principles can innovation competence education be based and how can an innovation competence-related intervention be successfully implemented in practice?
4. To what extent is the intervention, based on the design principles for innovation competence education, effective in increasing students' innovation competence?

Chapter 2 mapped students' perceptions of the learning environment with regard to innovation competence development and their self-perceived level of innovation competence. Students' perceptions of the focus on and relevance of innovation competence in their educational curriculum were also mapped, as well as the relationship between the learning environments and the self-perceived level of innovation competence. Data were collected from 130 Built

Environments students at eight universities of applied sciences in the Netherlands. Factor analysis showed satisfactory results for the reliability of the measurements of the different variables. The results showed that students rated their motivation level, creativity and belief in their own creative abilities slightly higher than their ability to solve ambiguous problems, their propensity to take risks and their self-perceived leadership. In addition, the students viewed their learning environment as moderately innovation-oriented on average, as all scores were around the midpoint, with attention to personal relevance being rated lowest, student negotiation as highest, and uncertainty considerations ranked in-between these two scores. Students' scores for the focus on innovation competence at the school/curriculum level showed a moderate level. With regard to whether developing students' innovation competence is relevant, students indicated that they found this somewhat relevant. Seven stepwise, multiple regression analyses were performed to determine the collective and unique predictive contribution of the learning environment, focus and relevance variables to students' total innovation competence and its individual components. These regression analyses showed that students' perceptions of personal relevance were positively related to their self-perceived leadership, energy and ability to solve complex problems. Perceptions of room for negotiation were positively related to creativity, belief in one's own creative ability and generally experienced innovation competence. The curriculum's perceived focus on innovation was positively related to self-perceived risk appetite. In all cases, the effect was relatively small, at about 5%. Nevertheless, all associations found were statistically significant. The results showed that universities of applied sciences should focus more explicitly and structurally on teaching and assessing innovation competence. These results suggested that students perceived the existing learning environments as less supportive than hoped for and demonstrated the need to implement the learning environments principles more explicitly. In students' opinion, their teachers were not (yet) strongly focused on innovation competence education.

The first study, presented in Chapter 2, found that in the opinion of students, teachers did not explicitly focus on innovation competence development in their teaching. Previous research into learning environments in different educational domains has shown that there are significant differences between teachers' and students' perceptions. In those studies, students' perceptions were generally less positive than teachers' perceptions. In the second study, presented in Chapter 3, we examined teachers' views on the relevance of innovation competence and their belief in their own creative abilities, and compared teachers' and students' perceptions of the learning environment. We also mapped teachers' perceptions of the focus on innovation competency at the college/curriculum level, the correlations between the perceptions of the learning environment and creative self-efficacy, the focus on teaching innovation competence and the relevance of teaching for innovation competence. Data were collected from 94 Built Environments teachers from eight universities of applied sciences in the Netherlands. Factor analyses and reliability analyses showed satisfactory results for all constructs. The results showed, on average, neutral perceptions for the focus on innovation competence development. However, scores showed relatively large variability between teachers. A number of teachers found innovation competence education to be highly relevant, while some were even negative about its relevance. This is a remarkable finding, given the relevance of innovation competence to society and economy. The results showed that teachers were confident in their creative self-efficacy. Differences between students and teachers in perceptions of their learning environment were also investigated. Teachers scored clearly higher than students on all variables. Statistically significant differences in perceptions were found for these learning environment variables: attention to personal relevance, taking into account uncertainty and allowing students to negotiate. The findings are consistent with previous studies comparing student and teacher perceptions. Four stepwise, multiple regression analyses were performed to determine the joint and unique relationships between teachers' scores on each of the learning environment scales, their creative self-efficacy, and their beliefs about the curriculum-level innovation competence focus. These regression analyses indicated that perceptions of relevance predicted significantly and positively the focus on innovation competence. Focus on innovation competence at the curriculum level was a significant positive predictor of taking account of uncertainty. Creative self-efficacy significantly predicted perceived room for negotiation by students. In all cases, between 6 and 11% of variance was an explained, which was relatively limited. Nevertheless, all associations found were statistically significant.

Design-oriented educational research advocates the development of a set of design principles based on existing empirical analyses and theoretical principles. These principles were used to support the design and development of an innovation competence intervention. The aim of the proposed design principles was not to create a set of mandatory procedures and processes for teachers to implement, but rather to bridge the gap between educational policy and practice. This gap is related to the fact that innovation competence-supportive learning in the Built Environments domain is not yet explicitly focused on innovation competence and its relevance for teachers and students was not well-established, as was apparent from the needs and context analysis reported in chapters 2 and 3. These results showed the need for an intervention that mainly focuses on teaching innovation competence through an explicit approach to innovation competence education. Based on the literature and the findings of the first two studies, six design principles were formulated for the design of an innovation competence-supportive intervention. The six design principles presented in Chapter 4 were based on various theoretical principles, practical insights and recommendations. The four-component instructional design (4C/ID) model for complex competences, constructive alignment, a simplified innovation process and constructivism formed the main theoretical basis for the six design principles, which are:

1. Define holistic but measurable learning goals;
2. Incorporate constructivist learning principles into the learning environment;
3. Base education on the sequence of the innovation process;
4. Teach students thorough creative techniques;
5. Ensure that innovation competence assessments are easy to use, systematic, consistent with the learning activities and concise but comprehensive enough to capture relevant aspects of innovation competence;
6. Focus assessments of student learning outcomes on the process rather than the product.

The six design principles are arranged according to the three aspects of constructive alignment, namely goals, teaching-learning activities and assessments. The goals described the intended learning outcomes, while the teaching and learning activities indicated a procedure. Finally, the assessment described the what and how of the innovation competence assessments. Goals, activities and assessments are formulated in terms of the three phases of the innovation process: problem identification, creative solution idea generation and solution implementation and evaluation. These design principles were the basis for the development of the innovation competency instructional prototype that was evaluated and tested in the next chapter. It involved a fundamentally different approach to teaching and learning, orchestrating learning activities aimed at fostering innovation competence in students. Students were asked to identify innovative problems and develop innovative solutions for tasks in the Built Environments domain. Some examples of task scenarios were making homes energy-neutral, developing mechanisms and interventions to limit flooding in flood-prone regions and identifying innovative problems and developing innovative solutions for road safety in central transport stations. The duration of the tasks varied from 2 to 8 weeks, depending on the year of study and task focus.

Chapter 5 focused on testing the effectiveness of the innovation competency intervention described in chapter 4. The intervention was refined through several iterations in Built Environments courses at three different universities of applied science. The intervention research, which used a mixed method approach, took place in an innovation competence course (15 ECTS), with 46 final-year students from one of the participating universities. Various data were collected. First, students had to complete a pre- and post-test questionnaire that asked about their own perceived innovation competence. Paired-sample t-tests comparing students' pre- and post-test scores showed that the increase in student scores for all three target learning outcomes was statistically significant: students were in reasonable agreement that they had learned to ask innovative questions, come up with creative solutions to the problem posed, and show that the solution developed for the problem was appropriate, while they were less likely to agree with these statements prior to the study. Improvement in scores for an overarching, combined competency was also statistically significant, with a large effect size. Second, the final products of the students were assessed through rubrics. Six pairs of teachers used a rubric with 22 items to jointly assess the products of 46 students. The end-of-semester assessment of students' final products by these teacher evaluators showed that the majority of the student had satisfactory results. The work of one student was considered poor and the work of two students was considered excellent by their raters. Third, group interviews with interested students and teachers were held at the end of the last day of the course. The purpose of the group interview was to gain insight into the views of students and teachers about the design and content of the course. Three groups of students (18 in total) were invited to participate in the group discussion. Two teachers were also interviewed about the innovative nature of the students' work. Student data were grouped by linking statements to the design principles, while teacher data were grouped by linking statements to the three learning objectives. Overall, the majority of teachers who assessed student work were satisfied with students' methodical approach in identifying problems and generating solutions. Teachers were satisfied with students' products, especially when the customer found the solution useful. Students' reflectivity was also an aspect teachers considered when determining student grades. The results of the student interviews showed that the innovation competence intervention promoted students' understanding of the innovation process from the students' perspective. The results of the group interviews were completely consistent and complemented the picture presented by the pre- and post-questionnaires. The students understood the steps and procedures in the tasks involved in coming up with an innovative question, and the creativity and the implementation sessions. Students were convinced that the procedures did not hinder their ability to think creatively or generate innovative ideas. Students also indicated that they had confidence in the transferability of the knowledge gained from the program to other disciplines. Overall, the analysis of both student self-assessment and student product assessment data reflected positively on the six design principles for innovation competence education. It can be concluded that, by carefully and deliberately taking into account important design principles for education of innovation competence, it was possible to design an effective and useful instructional intervention to promote students' innovation competence.

Scientific limitations and suggestions for future research

This dissertation has shown that students' innovation competence can be improved through an explicit and structured approach. Nevertheless, in addition to the answers, this thesis has some implications for future research on innovation competence-supportive education and learning environments. First, these studies were carried out in a particular educational domain at a particular university of applied sciences; implementing the intervention in other educational domains and at other universities of applied sciences will provide useful knowledge about the generalizability of the design principles. Second, beliefs about the relevance of innovation competence also need to be qualitatively examined to gain a more in-depth understanding of the relevance teachers attach to innovation competence. Third, the study focused only on teacher and student perceptions. Future investigations may also involve other staff of the educational organization, such as directors, team leaders and curriculum committees, and other organizational levels, such as upper, middle and lower management and staff departments. Finally, the intervention was characterized by an important and large role for and active involvement of the researcher during most phases. Future studies may aim to explore the balance between the actions of experts and researchers and the active engagement of educators needed to properly implement innovation competence-supportive interventions.

Practical implications

This dissertation contributes in various ways to the development and stimulation of students' innovation competence in higher education. First, this study has provided a more comprehensive and clear picture of innovation competence, on the one hand by distinguishing six characteristics of innovative professionals – creativity, leadership, creative self-efficacy, energy, risk propensity and complex problem solving – and on the other hand by distinguishing between three interconnected phases or processes – innovative problem discovery, generating creative solutions, and implementing and evaluating these solutions. Second, the study generated helpful tools and surveys to map students' self-perceived innovation competence, students' perceptions of the learning environment and teachers' beliefs and ideas of innovation competence (relevance). These surveys can be use to detect interest in innovation competence and to identify problem areas or areas for further improvement in innovation competence education. Third, this dissertation has created and produced educational materials and tools for assessment of the development of innovation competence. Teachers can use these tools to innovate their own education or to measure the effect of their own innovation attempts in education. Fourth and finally, this dissertation produced six design principles for the development of innovation competence focused interventions, that can be used to design new interventions and that can be used as checklist for existing interventions or courses.

Concluding remarks

In conclusion, the research in this thesis shows that students' innovation competence can be positively influenced by instruction. The findings of this study suggested that development of students' innovation competence takes place through explicitly coordinated teaching and learning activities, design, assessment and reflection. It was found that this innovation-supportive learning environment influenced the actual innovation competence of students and that the way of teaching (especially a better structured, balanced and more student-centred constructivist approach to teaching) had a positive influence on students' development of innovation competence. This dissertation has shown that every student has the potential to be innovative, and that teachers can fulfil their role in recognizing the innovation potential of students by creating a teaching and learning environment that promotes and encourages innovation competence. It is our sincere hope that this line of research will be continued, in collaboration with researchers and teachers from different fields, to jointly explore how innovation competence can be promoted through explicit education, so that all students can benefit by developing innovation competence.

Curriculum Vitae

Robert Ovbiagbonhia earned his MSc degree in architecture from Delft Technical University. As an architect, he worked for a number of renowned and internationally oriented architectural offices in the Netherlands and conceived and realised several high-standard projects in Europe and Africa. Robert has 13 years of diversified architectural design experience, both in academia and industry, and has experienced architectural design in a range of contexts, including product design, residential and commercial building design, and landscape and urban planning design. He currently works as a lecturer and research associate in the fields of architecture and building technology at the School of Future Environments at the Hanze University of Applied Sciences, Groningen. Robert's long-term goal is to drive architectural innovation by applying his multidisciplinary architectural and accademic expertise to design, analysis, instrumentation, and manufacturing challenges in both academics and industry.

Publications

The studies in this dissertation have been set up as or published in the form of articles. Two studies have already been published as articles in a peer-reviewed journal, one has the form of a dissertation chapter and one has been submitted for publication as article in a peer-reviewed journal:

Chapter 2

Ovbiagbonhia, A. R., Kollöffel, B. J., & den Brok, P. (2019). Educating for innovation: students' perceptions of the learning environment and of their own innovation competence. *Learning Environments Research, 22*, 387–407. https://doi.org/10.1007/s10984-019-09280-3.

Chapter 3

Ovbiagbonhia, A. R., Kollöffel, B. J., & den Brok, P. (2020). Teaching for innovation competence in higher education Built Environment engineering classrooms: Teachers' beliefs and perceptions of the learning environment. *European Journal of Engineering Education, 45*(6), 917-936. https://doi.org/10.1080/03043797.2020.1784097.

Chapter 4

Ovbiagbonhia, A.R., Kollöffel, B.J., & den Brok, P. (dissertation chapter). *Six design principles for fostering students' innovation competence in engineering education.*

Chapter 5

Ovbiagbonhia, A. R., Kollöffel, B. J., & den Brok, P. (submitted for publication). *Investigating the impact of innovation competence training in higher engineering education.*

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Acknowledgements

After years of working as a teacher at the Hanze University of Applied Sciences Groningen, School of Built Environments, I had the opportunity to do PhD research. The subject of my research was obvious, because an interesting process had just begun: the development of students' innovation competence. What a privilege that I was given the opportunity to do research for a number of years in an educational area where my heart lies. I have found the PhD program a great experience and have grown as a professional. I was able to step outside my own familiar frameworks and as a result gained a lot of new knowledge, skills and experiences. There was so much to read and that resulted in an enormous amount of new insights. There was also much to learn about research methods and academic writing, about publishing and presenting scientific work. And how disappointed I was when an article I was so proud of was rejected, but I also learned from this. The rock-solid confidence that my two supervisors had in me and the guidance and support I received from them kept me going in difficult moments. All of this has given me the energy to overcome all difficulties and complete my research.

And now here is my thesis, which marks the end of a process that I have enjoyed working on with so much pleasure. Of course, I couldn't achieve that without the support and help of others. In this place I would like to thank everyone who has helped me in many ways over the years. To begin with, I would like to mention the two managers who made the start of my research period easy. Thank you, Elvira Visser and Johan Hoekstra, for encouraging me to start this research project, in the confidence that I could handle such research. Thank you, Johan Hoekstra, for granting the preparation time for drawing up the grant proposal and for the confidence that the financing would work out. Thank you, Paul van Eijk, for signing my grant application form at the time, as Dean of the Institute for Built Environments, and giving me feedback during the delicate initial phase. Thank you very much, Marca Wolfensberger, for providing a basis from which to offer this research project to Hanze University of Applied Sciences. During my trajectory, the daily supervision was in the hands of Bas Kollöffel. Thank you, Bas, for sharing your expertise so freely with me and guiding me to the finish line; you really were an important success factor. Thanks to your years of experience in research and guidance, you always knew exactly what I needed at what time. Thank you very much, Perry den Brok, for your ideas and constructive feedback during my PhD trajectory. I could not have reached this level without you. You always knew how to keep the bigger picture in mind; you always knew exactly where my weaknesses were, but I also knew that a compliment from you was a very serious compliment. Perry and Bas, I am grateful to both of you for your unbridled energy in sharing your insights in detail. I have learned a lot from you, especially about building and structuring arguments, about the process of translating details into more general patterns, about accuracy and strategic choices in formulations. You complemented each other perfectly as supervisors and were always available for questions; feedback always came back in no time. You motivated me and helped me move forward. How lucky I have been with you as promoters! I'm going to miss our Skype meetings and in-depth conversations.

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