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The development of the Cognitive Affordances of Technologies Scale – from an observation tool to a self-reporting survey tool

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Tiivistelmä - Referat - Abstract

Tavoitteet. Tämän tutkielman tavoitteena on kehittää Cognitive Affordances of Technologies Scale (CATS) -mittaria. Mittarin tarkoituksena on löytää oppimisen kognitiivisia affordansseja erilaisista teknologiaa hyödyntävistä oppimisympäristöistä. Sitä käytetään koulutuksen kehittämiseen. Tässä tutkielmassa ei vertailla eri ryhmiä, vaan kuvataan, millaisia tarjoumia erilaiset oppimisympäristöt tuottavat oppijoille.

Teoreettinen viitekehys. Kognitiiviset affordanssit ovat ympäristön tarjoamia mahdollisuuksia eli tarjoumia, joita jokainen tulkitsee omasta perspektiivistään. Sulautetun oppimisen (blended learning) ympäristöt sekä virtuaalitodellisuudetta sisältävät oppimisympäristöt kuuluvat teknologiaa hyödyntäviin ympäristöihin. Aiemmassa tutkimuksessa CATS-mittaria on käytetty ainoastaan havainnointitutkimuksessa, ja se on sisältänyt seitsemän kategoriaa ja 41 kriteeriä.

Menetelmät. Neljän eurooppalaisen yliopiston opiskelijat ja yhden suomalaisen yrityksen työntekijät vastasivat muokattuun CATS-kyselyyn. Koko aineistoa (N = 134) hyödynnettiin mittarin kehittämisessä. Mittarin testaamisessa käytettiin muun muassa faktorianalyysiä. Pääryhmät olivat sulautuva oppiminen ja virtuaalitodellisuutta sisältävä oppiminen.

Tulokset ja johtopäätökset. Uudessa CATS-mittarissa on kuusi kategoriaa ja 27 kriteeriä. Pääryhmien osallistujat kokivat, että eniten tarjoumia tuli tutkimuspohjaisen oppimisen ja vuorovaikutuksellisen oppimisen kategorioista, joten sulautetun oppimisen ympäristö tarjosi samanlaisia oppimisen kognitiivisia affrodansseja kuin virtuaalitodellisuutta sisältävä oppimisympäristö. Tulos ei ole täysin yllättävä, koska kirjallisuuden perusteella virtuaalitodellisuus voidaan tulkita osaksi sulautettua oppimista. Tulevaisuudessa oppimisympäristöjen tutkiminen affordansseittain voi selkeyttää eri teknologioiden rooleja oppimisympäristöissä.

Avainsanat - Nyckelord

kognitiivinen affordanssi, Cognitive Affordances of Technologies Scale (CATS), sulautettu oppiminen, virtuaalitodellisuus (VR), oppiminen

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Tiivistelmä - Referat – Abstract

Purpose. The aim of this thesis is the development of the Cognitive Affordances of Technologies Scale (CATS) instrument. The purpose of the instrument is to is to map different cognitive affordances of learning in different technology-enhanced learning environments. The instrument is used to develop and improve education and learning modules. In this thesis, different groups are not compared, but it is explored what different learning environments offer for learning.

Theoretical framework. Cognitive affordances are offerings in the environment that everyone interprets from their own perspective. Technology-enhanced environments include blended learning environments and Virtual Reality (VR)-enhanced learning environments. In a previous study building on the CATS instrument, the instrument was only used in an observational study and it contained seven categories and 41 items.

Methods. Students from four European universities and employees of one Finnish company filled in the modified CATS survey. Data collected from all participants (N = 134) were used in the development of the instrument. In testing the instrument, e.g., factor analysis was applied. The main groups were blended learning and VR-enhanced learning.

Findings and conclusions. The new instrument has six categories and 27 items. Participants of the main groups reported having experienced the most affordances in the categories Inquiry-Based Learning and Discourse/Dialogic Learning. Hence, it seems that the blended learning environment afforded similar cognitive affordances of learning as VR-enhanced learning environments. This finding is not entirely surprising, as based on the literature, VR can be interpreted as part of blended learning. In context of educational implementation, exploring the learning environments by affordances could clarify the roles of different technologies in learning environments in future research.

Avainsanat - Nyckelord

kognitiivinen affordanssi, Cognitive Affordances of Technologies Scale (CATS), sulautettu oppiminen, virtuaalitodellisuus (VR), oppiminen

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1 Introduction

In 2020, technology as a part of the learning environment has become a significant part of teaching and learning. For example, the current COVID-19 pandemic has driven a large part of teaching and working life, at least momentarily, to distance learning and working. The challenge of this era is to find out what kind of technology should be invested in teaching for future working life skills. This study explores what kinds of cognitive affordances of learning different technology-enhanced environments offer to their users based on user experience. Cognitive affordances are offerings in the environment that everyone interprets from their own perspective and culture (Zang and Patel, 2006). For example, learning environments include enabling different forms of work or practicing different real-life situations.

Virtual Reality (VR; also known as Virtual Environment, VE) has for more than a few decades been represented as the new Golden Era of immersive learning and teaching by proponents of different digital learning environments, interactive and authentic learning. In present times, VR has become relevant again with the new platforms and lower prices, bringing it closer to the average consumer (Scavarelli, Arya & Teather, 2020). Indeed, VR-based solutions have been used rather intensively in many fields for simulation purposes. These fields include medicine (Riener, 2012), military training (Zyda, 2005) and engineering education (Sampaio, Henriques & Martins, 2010) among others in terms of creating authentic frameworks in which to train future professionals.

However, despite its obvious promise as the new breakthrough in education, far less is actually known of the real benefits of VR as for learning outcomes in the given contexts. In this thesis, the aim is to find out what kinds of different cognitive affordances are offered – or afforded – by different technology-enhanced environments based on the user experience. For this purpose, the learning environments were approached as blended learning environments (BLE) and VR-enhanced learning environments. In the bigger picture, the purpose was to find out possible blind spots in education and to develop teaching in the direction of cognitive affordances. An important part of achieving the goals was to evaluate and develop the performance of the CATS - Cognitive Affordances of Technologies Scale - instrument (Dabbagh, Conrad & Dass, 2010) – a tool that was originally developed for observational research, but in this thesis, was expanded and re-configured to be used as a self-report instrument for survey research.

The theoretical framework consists of three parts. The first part discusses cognition and cognitive science. The concept of affordance is then discussed, after which the focus is on the concept of cognitive affordance and how it can be measured. Finally, technology-enhanced learning environments are discussed. Blended learning and VR-enhanced learning environments are treated separately. They are not separate from each other as such, but for simplifying the terminology, they are in this thesis discussed as different entities.

The aim of the study was two-fold. The first part deals with the reliability and validity of the self-report survey instrument and its subscales. The purpose is to find out how many and what kinds of subscales are formed. In addition, the internal consistency of the instrument is examined. In the second part, cognitive affordances of learning reached by the different groups are presented.

This study is part of the Embedding Circular Economy into Product Design and Optimization (e-CirP) project (Grönman, 2019) that aims to develop new course material and learning modules for undergraduate students (Sandström et al., 2020). The project is described in more detail in section 4.2.

2 Theoretical framework

In this section, the concepts of cognition and affordance are introduced to pave the way towards the concept of cognitive affordance. Thereafter, the types of learning environments, in which cognitive affordances of learning will be measured in this thesis, are explored.

2.1 Cognition and cognitive science

The term *cognitive* refers to an individual's mental process (Danish & Gresalfi, 2018; Merriam-Webster, 2020b). Danish and Gresalfi (2018) define the term *cognition* as in influencing mental processes, while several other researchers use the terms synonymously as "the process of thinking" (see e.g. Halls, 2014, p. 2; MacLin, 2007, p. 564). An example of the former definition would be *cognitive consistency*, whereby people change their own perceptions to be consistent with others to get rid of an uncomfortable psychological state with its negative emotions (Marelich, 2007).

When dealing with cognition, knowledge plays a significant role. It can be divided into declarative and procedural knowledge. Declarative knowledge comprises facts about the object of knowing and procedural knowledge refers to the activity. (Halls, 2014.) Greeno, Collins and Resnick (1996, p. 16) proposed a theory of cognition and learning, which has three components: "the nature of knowing, learning and transfer, and motivation and engagement". When viewed from a cognitive perspective, knowledge translates as "general cognitive abilities" (ibid., p. 18) and management of different topics, while knowing includes structures for developing understanding and demonstrating competence. Learning is understood through conceptual learning, and transfer is approached through the achievement of people's understanding, and motivation and engagement are inherent properties of humans.

Metacognition has become a topic of interest to researchers since the 1970s (Seel, 2012). It means "'thinking about cognition'" which can be rephrased as

“’thinking about thinking’” (MacLin, 2007, p. 564). Through metacognitive processes, a person deals with one’s own thinking process (ibid). Metacognition is understanding his or her own thinking process, observing their own cognitive functioning, and organizing their own cognitive process (MacLin, 2007; Seel, 2012). In psychology, these definitions are called metacognitive *knowledge, skills* and *experiences,* respectively. In terms of metacognition, learners are the masters of their own knowledge depending on general intellectual abilities. Skills develop based on the problems being addressed. The individual must have general and specific knowledge as well as the ability to apply the knowledge in new situations (Seel, 2012).

Study of cognition belongs to the field of cognitive science (Levinson, 2011). Cognitive science studies an individual’s inner mind (Hutchins, 1995; Thagard, 2019) as data processing (Halls, 2014). Researchers have been developing cognitive research since the mid-1950s (Halls, 2014; Thagard, 2019). It was developed as an alternative to behaviorism (Halls, 2014; Hutchins 1995). Halls (2014) sees the challenge of cognitive science being the lack of neurochemical data from the field of brain research. In the context of cognition and this thesis, the main subcategory of cognitive science is psychology (Middle European Interdisciplinary Master's Proagramme in Cognitive Science, 2020; NYU, 2020) under which, in addition to cognitive psychology and cognition, there is social psychology and social cognition (Oppong, 2015). Social psychology was influenced by cognitive psychology in terms of cognition, giving rise to the concept of social cognition (Moskowitz, 2005).

Social cognition consists of our ability to deal with our own thinking and our relationship with other people (Pennington, 2000). It allows considering others in a social context through cognition, for example, by interpreting the emotions of others (De Jaegher, Di Paolo & Gallagher, 2010). Social cognition makes it possible to control social behaviors. The development of social cognition is influenced by two heritable factors, i.e. genes and culture. Social cognition utilizes various stimuli such as memory and motivation in the automatic and voluntary control of behavior (Adolphs, 2001). The three major processes of social cognition are *inter-*

preting information that we observe through our way of thinking and social context, *analyzing information*, and *storing information* into our memory where it can be recalled (Pennington, 2000).

The subtypes of cognition in the field of cognitive psychology are for example distributed and embodied cognition which are discussed next. *Distributed cognition*, a concept developed in the late 1980s, also entails the cultural aspect (Hollan, Hutchins & Kirsh, 2000). It extends the definition of cognition beyond one's mind (Hollan, Hutchins & Kirsh, 2000; Rogers, 2006). It entails "interactions between people, artifacts and both internal and external representations", which often do not need to be considered in traditional cognition research (Rogers, 2006, p. 731). Distributed cognition contains cognitive structures that are distributed among the inner mind and the environment, among people, and through space and time (Zhang & Patel, 2006). It breaks down the boundaries created by researchers when comparing internal and external activities and when comparing cognition and culture. Studies approaching distributed cognition apply cognitive strategies to interactional situations to study their operation (Rogers, 2006). Thus, it can be said that shared cognition has two perspectives: In the reductionist view, the group is viewed through individuals, while the interactionist view also sees value in interaction, in addition to the individual (Zhang & Patel, 2006).

In embodied cognition, cognitive processes are formed in sensory and motor processes (Davis & Markman, 2012; Glenberg, 2015). According to Wilson (2002, p. 625), in embodied cognition, "cognitive processes are deeply rooted in the body's interactions with the world". He studied embodied cognition trough six attributes for cognition because, in his view, embodied cognition should not be a single entity but should be viewed through six different perspectives (by situation, through time-pressure, "we off-load cognitive work onto the environment", environment being part of it, created for action, "offline cognition is body based") (ibid, p. 626). In his conclusions the information, at least in part, is that cognition is context-specific and takes place in real time in a real environment. In addition, we use the environment to store information for us, for example, due to our limited working memory capacity and living in a world there the goal of cognition is to guide action. Wilson sees as problematic the claim that when studying cognition, the influence of the environment must be considered. As the truest argument he sees that "off-line cognition is body based" (ibid., p. 626). It means that "even when decoupled from the environment, the activity of the mind is grounded in mechanisms that evolved for interaction with the environment—that is, mechanisms of sensory processing and motor control" (ibid., p. 626). The relationships of the concepts in the cognitive science field are presented in Figure 1.

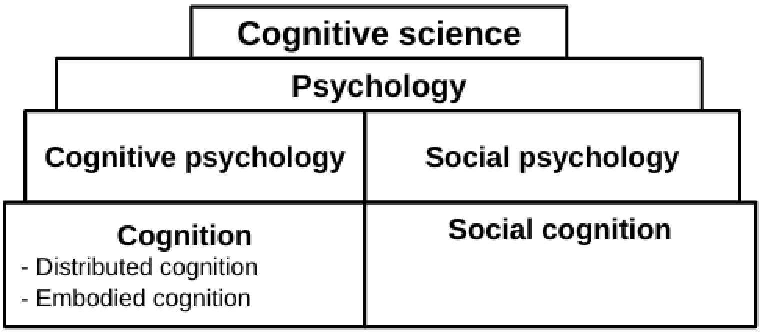


Figure 1. *The conceptual framework of cognition fields and related key concepts in this thesis.*

2.2 Cognitive affordances of learning

At first the concepts of affordance, artifact and their relationship are discussed. After priming the concepts from the preceding sections, cognitive affordance is introduced.

2.2.1 The concept of affordance

The creator of the concept of affordance, J. J. Gibson (1979/1986), defined affordance through that which the environment affords to those who live there. Before the potential user arrives in the environment, its affordances already exist. The environment does not change according to the needs of the residents, and it may contain inconspicuous affordances to its user, the potential of which remains untapped. In other words, affordances are a potential (Sandström et al., 2016) and enable action, but action may not materialize. The application of affordances is influenced by the environment as well as the potential user. For example, the environment affords water for the animals that live there regardless of whether the animals find or utilize the water.

Norman (1988) brought affordances to the fields of design and human-computer interaction and examined affordances by usability. The constraint of the object is wrong design in which case the user is unable to take advantage of the affordance without guidance. In 1999, Norman clarified the division between his term perceived affordance and Gibson's (1979/1986) affordance by calling it the real affordance (Norman, 1999). Real and perceived affordances are needed in different situations. For example, an icon on a computer screen is a perceived affordance because the user detects it.

In general, when talking about affordances, reference is made to observable affordances. However, affordance may also be hidden or a non-existent false affordance, which users think of as an affordance without it actually being it. Affordances and the perception of them can be interpreted by means of a four-field, which includes whether the affordance is real and whether it is perceived (see Figure 2). Affordances are studied by experiment because the user only perceives an affordance if it and its action are relevant to him or her (Gaver, 1991).

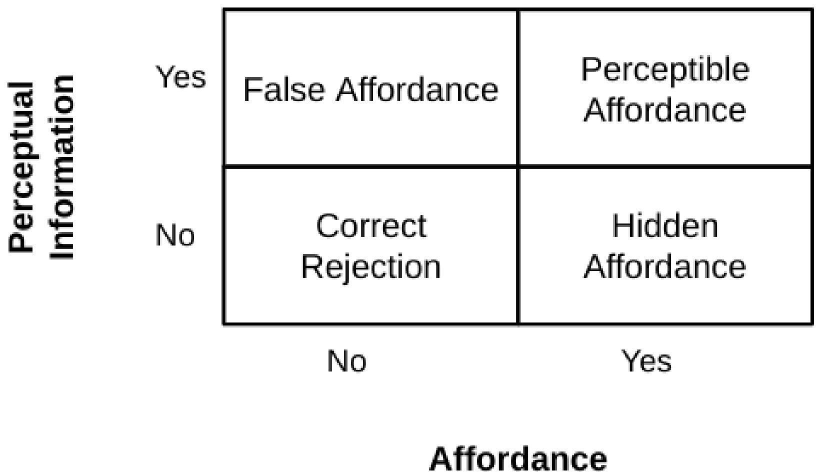


Figure 2. *Gaver's (1991, p. 80) four dimensions of affordances.*

Zang and Patel (2006) created five categories of affordances based on Gibson's (1979/1986) definition of affordance. Biological affordance describes what the biological environment provides, e.g. as edible berries that provide nutrition. Physical affordance provides opportunities for physical movement. Perceptual affordance guides people by vision. Cognitive affordance works according to the rules of a particular culture, e.g., the meanings of the colors of traffic lights instruct to act. Mixed affordance combines the benefits of different affordance categories, leading to more complex benefits, such as in this thesis context, technology-enhanced learning, which requires at least physical technology and cognitive learning skills.

Another way to divide affordances into categories is Hartson's (2003) division of affordances into four complementary design features. A cognitive affordance facilitates knowledge and it is consistent with Norman's (1999) concept of perceived affordance. A physical affordance facilitates operation and it corresponds to Norman's (1999) concept of real affordance. Sensory affordance facilitates user identification, and functional affordance makes it easier for the user to do so.

Perceptual learning is needed to find affordances from the environment. The perception and exploitation of affordances does not happen automatically. It is a skill to be learned and it may be more challenging in different situations. The user should look at affordances in relation to their own capabilities. Perceiving in this context consists of three levels: what is to be perceived in the environment, what is the information for perception and how the process of perceiving works (Gibson and Pick, 2000).

When talking about affordances, it is also important to address the meaning of artifacts. Affordance consists of a set of characteristics in the form of artifacts (Gaver, 1991). Affordances describe the relationships between designers, artifacts, and users (Maier & Fader, 2006). An artifact is often an object made or shaped by human (Merriam-Webster, 2020a). The analysis of artifacts considers whether they form the desired well-designed groups of activities (Gaver, 1991). The analysis also considers whether the artifact improves a person's ability to function (Norman, 1991).
Artifacts have a connection to virtual reality in addition to affordances. Simon (1996) opens the concept of artifacts in his work *The Sciences of the Artificial* which deals with natural and artificial environments. All artifacts are part of the

environment and many of them can be observed visually and auditively. Artifacts are adapted to people’s needs and they change with their needs. The artifact is examined in terms of its structure and the environment in which it is located. According to Norman (1991) an artifact can also affect cognitive function – cognitive artifacts are “artificial devices that maintain, display, or operate upon information in order to serve a representational function" (ibid., p. 17). Paavola and Hakkarainen (2014) presented knowledge artifacts which are for example documents and design artifacts. Processes that convey artifacts are part of the base of learning and play a role in understanding cognition.

2.2.2 Identifying and measuring cognitive affordances of learning

Cognitive affordances are indications of potential use in the environment that everyone interprets from their own perspective and culture (Zang and Patel, 2006). For example, a learning environment can offer different ways of working such as group work or different tasks that describe the working life skills needed in the future. Cognitive affordance is a user-centered design feature which facilitates learning something (Dabbagh, Conrad and Dass, 2010; Hartson, 2003).

Learning can take place interactively between technology and cognition (Dabbagh, Conrad and Dass, 2010). The elements of the cognitive affordance should be interpreted as motives for action (Jorba, 2019). Cognitive affordances are formed from “intuitive understanding or representations in a variety of media” (Sutcliffe, 2010, p. 45). Cognitive affordances include, for example, informativeness (Proust, 2016). According to Metzinger (2017), Gibson's (1979/1986) concept of affordance is the same as cognitive affordance. He bases his argument on the fact that cognitive affordances do not exist in individual places, the user's scheme of things must be noticed, and the user must be engaged to take advantage of affordances.

Concepts parallel to cognitive affordance are social, pedagogical, and educational affordances, which are discussed next. Social affordances are features of environments, which transfer an interactively relevant social context (Kreijns, Kirschner & Jochems, 2002). They describe how the perspective of social interaction has been considered in the design (Bradner, 2001). Pedagogical affordances support or limit the achievement of educational goals. Identifying pedagogical affordances can promote learning in the right direction (Airey & Eriksson, 2019).

The term *educational affordance* was coined by Kirshner (2002). By the word 'educational', he refers to learning in an institutional setting. Educational affordances are individual's action and experience. They are also properties of an artifact which determine whether the activity in question is possible in a particular context and what kind of learning is possible for a particular person. Educational affordance in distributed learning groups and social affordance require two types of interaction to function. First, there must be a reciprocal relationship between the environment and the people. The environment should respond to the social intentions of the participants as they emerge. Instead, social affordances should be relevant and should support or anticipate learning or social intentions. Second, there must be a perception-action coupling.

As shown above, the definition of cognitive affordance is not completely uniform across different researchers and cannot be fully distinguished from definitions of related concepts. In 2010, Dabbagh, Conrad and Dass began to develop the Cognitive Affordances of Technologies Scale (CATS) instrument to identify cognitive affordances. It was created to be used for observation during classroom lessons and self-used VR. Its intended uses are evaluating or increasing the cognitive affordances in a technology-supported learning environment, planning learning activities from the perspective of a specific affordance, and training and using affordances as part of planning the teaching. The goal is to figure out how the learning technologies were used by students (Dabbagh & Dass, 2013).

In the development process, 99 cognitive criteria were identified. The suitability of the claims was assessed in relation to a technology supported learning environment (Dabbagh & Dass, 2013). For example, the Self-Regulated Learning category has items such as Time Management and Self-Evaluation (Dabbagh, Conrad & Dass, 2010). All items are listed in Appendix A. The CATS instrument consists of seven categories of cognitive affordances with 41 cognitive criteria:

- Experiential Learning (8 items)

- Discourse/Dialogic Learning (4 items)
- Supportive Learning (7 items)
- Learn by Doing (4 items)
- Critical Thinking (5 items)
- Conceptual Change (5 items)
- Self-Regulated Learning (8 items) (Dabbagh, Conrad & Dass, 2010).

A pilot course was for economics students, and the topic was explored through role-playing and discussion about personal experience. Role-playing games were implemented using simulation software and computer-based VR called Second Life. The course explored the interaction between cognition and technology. As a result, classroom and VR teaching enabled almost equally as many affordances, but from different categories. Classroom teaching produced *Discourse/Dialogic Learning* categories of learning affordances, while VR teaching produced *Experiential Learning* and *Learn by Doing* categories. As an overall result, CATS became a tool for enhancing and enriching learning experiences by utilizing the pedagogical and cognitive affordances of learning (Dabbagh & Dass, 2013).

2.3 Technology-enhanced learning environments

At first, the concept of learning environment and its properties are briefly defined, primarily through blended learning environments (BLE). Then, BLEs and Virtual Reality (VR) -enhanced environments are introduced. Although VR-enhanced learning environments can be interpreted as belonging to blended learning environments, they are interpreted in this thesis as their own environments.

2.3.1 Blended learning environments

In the past decade, educational needs have transformed with the change of society towards the use of technology in learning and working. Blended learning can answer for the change. The background factors of blended learning include the rapid development of technology and the changed demands of working life (Allan, 2007). Blended learning takes note of the globalization of the business world which must be considered when designing modern learning environments (Hofmann, 2018).

Blended learning can be understood in many ways, but most commonly it involves the use of online media in a course that retains elements of face-to-face learning to support learning (Köse, 2010; MacDonald, 2008). It consists of a mixture of different models and pedagogical approaches which are put together in a context-appropriate way to promote learning (Carman, 2005; Driscoll, 2002). Driscoll (2002) argues that the definition of blended learning depends on the context. Blended learning could mean

1. Utilizing virtual technology in teaching.
2. Optimizing teaching by mixing different pedagogical approaches.
3. Combining technology with face-to-face teaching.
4. Combining technology and working life skills.

Allan (2007) agrees with Driscoll (2002) in many ways about blended learning. He sees blended learning as a holistic approach to learning, which includes reality and virtual aspects (see Figure 3). It blends different approaches such as traditional classroom learning, tools based on technology, and working life learning. He believes that the implementation of learning should be flexible by reducing traditional face-to-face teaching. At the same time, new ways of learning should be developed, and new technologies should be allowed to be tried out. Learning should be able to be implemented for large groups, and learning should combine skills used in working life.

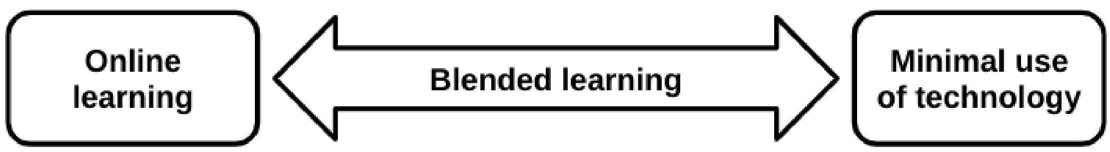


Figure 3. *Blended learning continuum (Allan, 2007, p. 5).*

Blended learning is cost-effective, and it can enable better learning outcomes (Hockly, 2018; Köse, 2010). Software and hardware are constantly becoming more accessible to everyone (Hockly, 2018). Effective education combines blended learning with technologies and between students and teachers and among students (Köse, 2010). Hofmann (2018) maintains that blended learning includes experiences outside the curriculum, which differentiates it from traditional learning. She believes that modern blended learning has four dimensions: what, how, where and when. Nowadays the last one is most important for learners when learning is not connected with specific time. Carman (2005) instead divides a blended learning process into five different stages which are real time virtual lectures, independent online assignments, virtual collaboration between students, assessment and reference materials.

Overall, blended learning has benefits for learners, teachers and organizations (Driscoll, 2002). Learners benefit from holistic understanding of learning and diverse approaches which complement each other. Blended learning mixes traditional lectures, real-time e-learning, and self-regulated learning (Singh, 2003). Utilization of e-learning can be moved step by step through blended learning, which helps teachers. At the organizational level, the benefit is to supplement existing courses with e-learning elements (Driscoll, 2002). Also, it is possible to include more participants in the taught entity regardless of time and place which allows cost optimization (Singh, 2003).

2.3.2 Virtual Reality -enhanced learning environments

Jaron Lanier coined the term *Virtual Reality* (VR) (Powell, 1996; Steuer, 1992). However, already over thirty years earlier Ivan Sutherland (in 1963, according to Muhanna, 2015) worked on a concept close to VR, and in the 1970s Myron Krueger (1992, as cited in Muhanna, 2015) introduced a concept about artificial reality. There have also been others working on the same phenomena over the years using different names for the same phenomenon (Muhanna, 2015). For some, virtual means artificial (Blade & Padgett, 2002; Milgram and Kishino, 1994), and VR “is a purely synthetic environment that the user interacts with" (Sherman & Craig, 2018, p. 19).

VR is created by humans (Neves, 2008) and it can look like a real or fictional world (Blade & Padgett 2002; Lorenzo, Pomares & Lledó 2012; Milgram and Kishino, 1994; Milgram, Takemura, Utsumi, & Kishino, 1995). VR is synthesized to feel like the real world (Brown, 2008; Milgram & Kishino, 1994; Lorenzo, Pomares & Lledó, 2012; Simon, 1996). We feel the world that we see as real, even if we are inside VR because of the inherent property of our brain forms a coherent world around us (Kelly with Heilbrun & Stacks, 1989). Woolgar (2002) even states that the more virtual the environment, the more authentic it feels.

In a VR simulation, the participants are in the main role because they interpret VR in their minds from their own context. They can interact with VR but also with each other which makes collaborative experience possible. (Sherman & Craig, 2018.) Woolgar (2002) recommends using VR as a support for the real-world activity and not as a substitute of it. The simulation aims to describe real world action or solve problems from the real world such as pilot training and anticipating the impact of architectural decisions (Brown, 2008). Lanier saw simulation's potential in the medical field in learning surgeries and enabling people with disabilities to experience what their physical reality does not allow (Kelly with Heilbrun & Stacks, 1989).

VR scenarios allow training in real life situations without risk or high cost for example in industrial fields. It also limits the need of travel to get access to specific working conditions and make distance collaboration possible for example in emergency response training. (Cobb, D'Cruz, Day, David, Gardeux, van den Broek, van der Voort, Meijer, Izkara & Mavrikios, 2008.) The disadvantage of the simulation is the aftereffect that the participant can experience when returning to the real world (Blade & Padgett, 2002).

VR exists even if it is not displayed (Sherman & Craig, 2018). To experience VR, the participants usually wear physical gear which affects three out of five senses (Kipper & Rampolla, 2012). VR technologies can split to three categories, which are hand based, stationary and head based. In hand-based technology, the participant experiences VR through a smartphone or tablet. In stationary technology, VR participants do not wear physical hardware because the projectors are part of the room-like experience space. The most known stationary application is the

CAVE system (Sherman & Craig, 2018). Head-based display is “any display in which data are presented in a heads-up fashion” (Milgram & Colquhoun, 1999, p. 1177).

Ivan Sutherland invented the first head display glasses in 1969 (Kelly with Heilbrun & Stacks, 1989). Glasses and helmet fall into the head-mounted display subcategory. Those displays allow to see VR in the same way as the physical world while turning one’s head because position-tracking follows the participant's head movements. Other head-based displays are a projector mounted on the participant's head, where VR projects to the walls, and a display which uses smartphones in a framework. (Sherman & Craig, 2018.) In addition to visual image, audio plays an important role in VR (Galantay, Torpus & Engeli, 2004; Milgram & Colquhoun, 1999), because the auditory stimuli create a suitable atmosphere for VR, which then enables a high level of immersion for participants (Galantay, Torpus & Engeli, 2004).

Traditionally in VR, participants are entirely immersed in a completely synthetic world (Azuma, 1997; Lorenzo, Pomares & Lledó, 2012; Milgram, Takemura, Utsumi & Kishino, 1995). Immersion feels like being physically on the spot (Blade & Padgett, 2002; Sherman & Craig, 2019). The more immersion it contains, the stronger the experience (Blade & Padgett, 2002). Immersion is a really felt, subjective experience for the individual (Dede, 2009). Immersion can divide into mental and physical immersion.

In general, the VR community uses the concept of *presence* instead of mental immersion (Sherman & Craig, 2018). Presence translates as the participants’ feeling being part of VR (Blade & Padgett 2002; Sherman & Craig, 2018.). Presence intertwines with social presence and social cognition (Riva & Mantovani, 2014). If participants can interact in VR, they are part of a multipresence experience (Sherman & Craig, 2018). Physical immersion is possible if technology gives stimulus for the whole body or augments stimulus for parts of it. For example, physical immersion happens when VR gives feedback on a participant's physical location (Sherman & Craig, 2018).

Finally, *Augmented Reality* (AR) is related to VR (Milgram et al., 1995). AR falls between real and virtual environments because in AR, the participant can see the real world and virtual objects simultaneously (Azuma, 1997; Milgram & Kishino, 1994; Neves, 2008; Sherman & Craig, 2018). AR also has the feature of utilizing information about the real world (Azuma, 1997). In AR, participants are not immersed in the virtual world (Azuma, 1997; Neves, 2008) and they can interact with each other in real time (Azuma, 1997; Sherman & Craig, 2018). AR is observed from the real world through display (Blade & Padgett, 2002; Milgram et al., 1995; Neves, 2008) and interaction happens based on location (Sherman & Craig, 2018). A well-known example is Pokémon GO mobile game that became the first popular AR game (Paavilainen et al., 2017).

Mixed Reality connects reality to VR through AR which breaks down perception of real and virtual, being completely separated (Milgram & Kishino, 1994). Milgram et al. (1995) call it *the Reality-Virtuality continuum* (see Figure 4). The figure's double-headed arrow can be understood as a linear slider, moving from real to virtual environment (Mann, Furness, Yuan, Iorio and Wang, 2018).

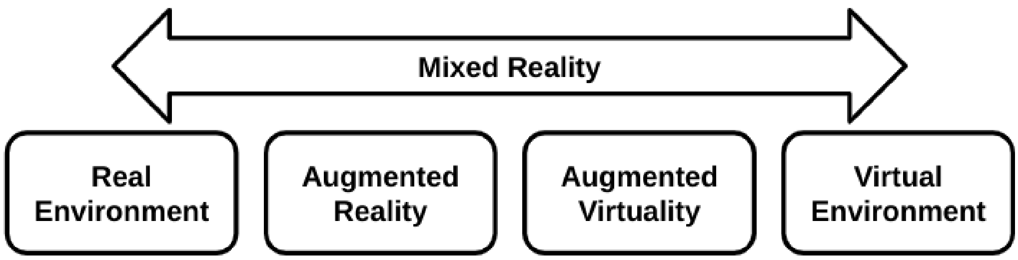


Figure 4. *The Reality-Virtuality continuum (Milgram & Kishino, 1994, p. 1321).*

2.4 Developing the survey instrument: How to ensure reliability and validity?

Liu (2010) presents a list of 10 steps formed by Crocker and Algina (1986) for the development of a standardized measurement instrument, for the instrument to meet the requirements of validity and reliability:

1. Define the rationale for the need of test results.
2. Define context-relevant behavior.

3. Create test properties based on defined behaviors.
4. Assemble the preliminary pool of items.
5. Review and revise items.
6. Pilot testing and revising items.
7. Extensive pilot testing in the target group.
8. Perform statistical tests and exclude items which do not meet the criteria.
9. Perform reliability and validity studies.
10. Create guidelines for interpreting results.

The development process begins with the definition of the research objectives and the formulation of a research problem (Kasunic, 2005; Pett, Lackey & Sullivan, 2003; Liu, 2010). It should be based on previous research (Ronkainen, Karjalainen & Mertala, 2008). The instrument should be logical in appearance, proceeding thematically (Sue & Ritter, 2007) so that a respondent knows how to proceed (Ronkainen, Karjalainen & Mertala, 2008). The instrument and its items should be linguistically simple and clear (Denscombe, 2010, p. 156; Pett, Lackey & Sullivan, 2003). Items can be performed e.g. in the form of Likert-scale statements which must be worded in such a way that they can be interpreted in only one way (Liu, 2010). The average value of the Likert scale can be interpreted not only as a neutral opinion, but also as an argument that one cannot comment on an argument (Ronkainen, Mertala & Karjalainen, 2008). More important than individual claims, is to consider the whole that the instrument measures (Pett, Lackey & Sullivan, 2003).

The target audience needs to be precisely defined so that they can be reached comprehensively, and the survey can be targeted to them (Denscombe, 2010; Kasunic, 2005; Ronkainen, Karjalainen & Mertala, 2008). The survey should be piloted in the target population (Kasunic, 2005; Ronkainen, Karjalainen & Mertala, 2008). Tests and development by the research team are done before the pilot test and are not counted in for the pilot testing (Kasunic, 2005; Ronkainen, Karjalainen & Mertala, 2008). The pilot testing reveals the problems and inefficiencies of the claims as well as the challenges of the survey (Kasunic, 2005). A survey is the most effective way to collect data if there are many respondents and they are not in the same location (Denscombe, 2010).

Gericke et al. (2019) developed a survey instrument to measure sustainability consciousness. It has three dimensions which were divided into three sub-categories. Items were measured using a Likert-scale. As mentioned earlier, the indicator should be based on previous research, which in this case were themes defined by UNESCO. In the analysis, they found some of the questions to be challenging to answer for people living in different cultures, but for the most part the survey was suitable for different people living in different areas. They created their own model which was tested using factor analysis. A shorter version of the survey was processed for quick use. The abbreviated instrument was constructed based on items with the highest factor loads. The clearest way to use the instrument is to simply calculate the means and standard deviations of the respondents. This is possible because of internal consistency which was found out by Cronbach's alpha values.

Schmid, Brianza and Petko (2020) developed a self-report questionnaire to measure competence of teachers. They studied whether the existing instrument containing seven sections would remain functional even if it were shortened. Items were removed based on factor loadings, discrimination of items and theoretical reflection. Another example of survey development is a questionnaire for measuring internet skills (van Deursen, van Dijk & Peters, 2012). A different approach, compared to studies presented earlier, is to compare correlations by Pearson's correlation coefficients. When examining the results, it must be considered whether the dimensions defined in the theoretical examination come to the fore. There should be a correlation within the dimensions, but not between the different dimensions, so that they clearly measure different things.

Reliability of a study refers to repeatability i.e., another researcher would with similar data and set-up conclude more or less similar results, and validity describes how well the selected phenomenon was measured (Liu, 2010; Metsämuuronen, 2006). Reliability's assessment dimensions are internal consistency, reliability, and measurement error. The quality of the instrument is improved by a low measurement error, which results in higher reliability (Scholtes, Terwee & Poolman, 2011). The error may also be due to other reasons such as the test author (Liu, 2010). The exact number is not defined for the reliability assessment except that when given a value of 1, it is completely reliable and when obtained a value of 0, it is completely unreliable. Internal consistency describes the uniform belonging of items to the background structure. This can be determined by using factor analysis, and internal consistency is determined by calculating Cronbach's alpha. The value of adequate correlation is above 0.70 and below 0.95. When the value is greater than 0.95, the instrument may have too many items evaluating the same background structure (Scholtes, Terwee & Poolman, 2011).

Valid studies measure the desired phenomenon (Heikkilä, 2008). They evaluate the success of the measurement process and the adequacy of the justification for the results (Liu, 2010). Validity consists of aspects of content, construct and criterion. As for content validity, the instrument's items should be considered in light of relevance and comprehensiveness (Metsämuuronen, 2006; Scholtes, Terwee & Poolman, 2011). The instrument should also consider the target group. Content validity does not have specific criteria because it is based on the researcher's subjective interpretation. Construct validity refers to a stronger correlation between similar concepts as compared to other concepts (Metsämuuronen, 2006). High correlation refers to the functionality of the instrument's structure (Liu, 2010). It also includes setting hypotheses which should present the expected internal relationships and possible differences between the groups. The structural validity defined by factor analysis includes to what extent the results obtained with the instrument reflect the structure of the instrument (Scholtes, Terwee & Poolman, 2011). Criterion validity compares the values obtained with the same instrument with those obtained in the other context (Metsämuuronen, 2006).

3 Research questions

In this section, the hypotheses leading to the research setting, and the research questions, are set out.

Hypotheses

This thesis approaches the research setting through the following hypotheses that structure the research questions and lay out the expected key outcomes of the study.

1. The structure of the CATS instrument is valid and reliable (consisting of the original seven subscales).
2. The instrument can be used in assessing differences of technology-enhanced learning in traditional and VR-supported learning environments.

According to the results of Dabbagh and Dass (2013), the VR group should experience the most cognitive affordances in the categories *Experiential Learning* and *Learn by Doing*. If the blended learning (BLE) group in this thesis works in the same way as the face-to-face group of Dabbagh and Dass, the BLE group should report the most cognitive affordances in the Discourse/Dialogic Learning category.

Research questions

1. How valid and reliable is the structure of the CATS instrument?

   1.1 What is the structure of the CATS instrument?

   1.2 How internally consistent is the original CATS instrument and its subscales, and how internally consistent is the identified refined version of the instrument?

2. Which cognitive affordances of learning do students experience in different technology-enhanced learning environments?

   2.1 Which cognitive affordances of learning do students experience in VR-supported and blended learning environments?

   2.2 Which cognitive affordances of learning do students experience in different courses?

4 Method

4.1 Methodological approach – design science research

Design science research (DSR) was chosen as the methodological approach for the development of the CATS scale as a tool to assess students' experiences of technology-enhanced learning by VR in the e-CirP project. DSR has been used in the field of information science (IS) for at least 30 years (Peffers, Tuunanen & Niehaves, 2018). The goal on DSR is to provide innovative solutions and solve a new or a known specific problem in a better way for the organization's business needs (Hevner, March, Park & Ram, 2004).

Problems are solved by creating artifacts in DSR (Hevner & Chatterjee, 2010; Hevner et al, 2004; Johannesson & Perjons, 2014; March & Smith, 1995). They can be physical objects, drawings or methods to help people solve problems for their practical needs (Johannesson & Perjons 2014). In addition to creating an artifact, it is important to monitor its impact on the environment (Johannesson & Perjons, 2014) but also the environment's impact on the artifact (March & Smith, 1995). The artifact must be precisely defined and a coherent whole, which has a novelty value and can produce effective solutions. The artifact is evaluated quantitatively, empirically and qualitatively in the given context (Hevner et al., 2004).

Several researchers have made guidelines for implementing the DSR method. For the e-CirP project's scale development, Hevner's (2007) Design Science Research Cycle model was chosen, and it is based on the model by Hevner et al. (2004). The original model's main priority was to utilize technology as part of the design (Hevner et al., 2004). Hevner's (2007) model has three background components – *environment, DSR* and *knowledge base* – and three cycle elements, *Relevance*, *Design* and *Rigor* cycles. The environment component entails application domains, and the knowledge base refers to foundations such as scientific theories. Hevner's (2007) model in the context of this thesis is presented in Figure 5.

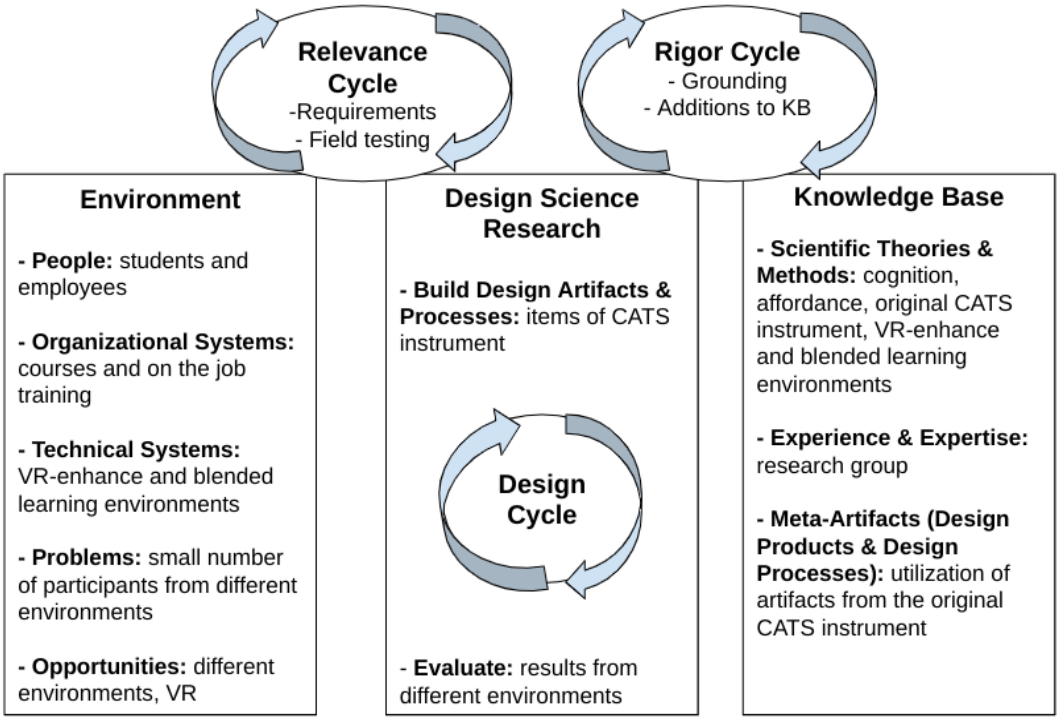


Figure 5. *Utilization of the Design Science Research Cycle model in this thesis context based on Hevner's (2007, p. 88) model.*

4.2 Context of the study

This study is part of the Embedding Circular Economy into Product Design and Optimization (e-CirP) project (Grönman, 2019) that aims to develop new course material and learning modules for undergraduate students (Sandström et al., 2020). The goal of the project is to develop inter-university circular economy (CE) courses in collaboration with 6 European universities (Sandström et al., 2020). The course is targeted at undergraduate students of several engineering disciplines, sustainability assessment and product design (EIT Raw Materials, 2020). The project is funded by EIT Raw Materials (Grönman, 2019; Sandström et al., 2020). This thesis positions itself at the first year of a three-year project (Sandström et al., 2020), and it describes the first cycle of piloting CATS as a self-report instrument for survey research.

According to Sandström et al. (2020), the seven parties to the project can be divided into three groups. Academic expertise is represented by Lappeenranta-Lahti University of Technology (LUT), Technical University of Denmark (DTU), Delft University of Technology (TU Delft), the University of Padova and the University of Helsinki. Fraunhofer Society represents application-oriented education and Outotec as an industrial company partner promotes the integration of working life requirements in teaching. LUT is the lead partner of the project and University of Helsinki supports the educational and learning design. This thesis study has been written in the research group of the Campus Learning and Development Initiatives Hub (Caledonia HUB) at the University of Helsinki (https://www.helsinki.fi/en/researchgroups/campus-learning-and-development-initiatives). The courses at the beginning of the project can be found in Table 1.

Table 1. *Partner universities with circular economy courses in e-CirP.*

University	CE course	Country
LUT University	Technical Cycle in Circular Economy (Sustainability Science) Product Design and Production Processes (Mechanical Engineering) Sustainable Design (Mechanical Engineering)	Finland
DTU	Sustainability in Engineering Solutions Circular Life Cycle Engineering	Denmark
TU Delft	Sustainable Design Strategies Project XL	Netherlands
Padova	Circular Economy	Italy
Fraunhofer	Sustainability in Engineering	Germany

The choice of courses was influenced by their suitability for CE (Sandström et al., 2020). The concept of CE is currently much raised by companies, the EU and national governments. Its attractiveness is based on the involvement of business communities towards meeting the goals of sustainable development. Also, 21st century and work-life relevant skills are well adapted in a timely topic such as CE that integrates sustainability thinking and digital competencies into solving real-life challenges related to material use and depletion, climate change, and for instance protecting the world's seas. CE and sustainability engineering are developing fields and inherently future-oriented. Also because of this, the work life requirements are forward leaning and as such, interesting for the progress made in skills and competences. However, research on circular economy as a concept is fragmented and incomplete at the moment (Korhonen, Honkasalo & Seppälä, 2018). During the courses, the students analyzed real cases from related industries. The courses were currently separate from each other, but efforts are being been made to add a flipped learning approach to all of them. All courses also utilized technology in some form. The next phases of the project will explore VR's potential as part of teaching. (Sandström et al., 2020.)

A second data set was utilized in order to explore the possibilities and potential of VR in supporting learning. Data were from MR Hub's (https://www.helsinki.fi/en/researchgroups/mixed-reality-hub) project where VR was utilized as a part of teaching at Seinäjoki University of Applied Sciences (SeAMK) in Finland. The learning modules were Automotive and Machinery Engineering Laboratory courses. VR was used via head-mounted display (see section 2.3.2). VR platform was from Finnish forest machine company, where students in groups of four dismantled the crane and harvester head during three lessons and at the same time answered questions related to the topic. After that, there was a discussion about learning and work.

This thesis also utilizes a third, additional, data set that complements the data gathered for purposes of validating the instrument. Data also come from MR Hub, but they have been collected from employees of a Finnish company.

4.3 Instrument of the study – CATS

The new version of the CATS instrument is based on the observation instrument developed by Dabbagh, Conrad and Dass (2010). The researchers of MR Hub and Caledonia Hub developed the observation tool into a self-report survey. The first version of a new CATS instrument (in Finnish) was developed by researchers of MR HUB at the University of Helsinki and piloted in a Finnish company. The second version of the CATS instrument (in English) was developed in collaboration with MR and Caledonia Hub to be piloted in the e-CirP project.

The combined research group formulated questions in iterative cycles to have the statements in a clearer language so that the translations and back-translations would be formulated in as clear and unambiguous a language as possible. At the same time, two new items were added to the instrument to harmonize the categories. The items added were Independent thinking and understanding to the Experiential Learning category and Learning by doing to Learn by doing category.

One member of the research team tested a pilot version of the CATS survey in the Finnish company with non-native English speakers. The question that the items covered was formulated according to the context. The question for the e-CirP courses was *Which skills or activities have you used in the Circular Economy course that you are now taking?*

The survey's word choices were modified based on responses from the test group, after which a back-translation was performed. A few examples of modified items are presented in Table 2. Some of the modified items were more descriptive than the original item. They were more approachable in their word choices and contained examples relevant to the target group. A few of the items remained the same such as coaching and problem solving. The original as well as the new CATS surveys in Finnish and English can be found in Appendix A.

Table 2. *Examples of the modified items from the original CATS to fit a self-report survey in the context of this thesis.*

Category	Original item	New item
Experiential Learning	Role Playing	Taking different roles (e.g., salesperson, service technician, manager etc.)
Discourse/Dialogic Lear-ning	Articulation	Oral and written communication
Conceptual Change	Transfer	Adapting and applying new ideas into practice
Self-Regulated Learning	Motivation - Extrinsic	Motivating others

The CATS instrument was selected as a basis for a self-report survey instrument to explore perceived affordances in different technology-enhanced learning environments. The instrument has seven categories of cognitive affordances with 43 cognitive criteria:

- Experiential Learning (8 items, 1 new item)
- Discourse/Dialogic Learning (4 items)
- Supportive Learning (7 items)
- Learn by Doing (4 items, 1 new item)
- Critical Thinking (5 items)
- Conceptual Change (5 items)
- Self-Regulated Learning (8 items) (Dabbagh, Conrad & Dass, 2010).

More about the development of the original CATS instrument is in section 2.2.2.

4.4 Data gathering

All survey data were collected for the development of the CATS scale. The survey was conducted in English (n = 101) and Finnish (n = 33). The purpose of the survey was to test the relationship of the background variables on the responses. The survey data were collected through an electronic questionnaire (Microsoft Office 365 Forms) using a 7-point Likert scale where each statement had to be answered. The invitation to participate in the survey was sent to students by the teachers of the pilot CE courses at the end of the courses in December 2019, January 2020 and June 2020. A total of 49 students responded in the survey from CE courses. SeAMK data were gathered by the teacher of the Automotive and Machinery Engineering Laboratory course. Participants (n = 29) were second- and fourth-year engineering students. Data were collected after the courses in February and March 2020. The additional data from employees of the Finnish company (n = 56) were gathered by a master's student of the MR Hub. Data were collected from July to November 2019.

The demographic background and response percentage of the participants are shown in Table 2. Of the three courses, all participants responded to the questionnaire. From Padova, 41% of the course participants submitted a completed survey, and 7% answered at Fraunhofer. The response rate of the workplace employees was not measurable. Work experience of the respondents can be found in Table 3. On average, the course participants had less work experience than respondents in the company. The differences between CE and SeAMK courses were modest.

Table 3. *Demographic background and response percentage of the respondents.*

Group	Frequencies (N = 134)	The response percentage
Technical Cycle in Circular Economy (LUT)	15	100 %
Sustainability in Engineering (Fraunhofer)	5	7 %

Sustainability in engineering solutions (DTU)	9	-
Circular Life Cycle Engineering (DTU)	5	100 %
Circular economy (Padova)	15	41 %
Automotive and Machinery Engineering Laboratories (SeAMK)	29	100 %
Workplace	56	-

Table 4. *Work experience of the respondents.*

Work experience	From any field	From the field your studies prepare for
CE courses		
0 – 1 years	16	33
1 – 5 years	20	14
over 5 years	13	2
SeAMK		
0 – 1 years	6	-
1 – 5 years	20	-
over 5 years	3	-
Workplace		
0 – 1 years	1	-
1 – 5 years	2	-
5 – 10 years	14	-
10 – 20 years	20	-
over 20 years	19	-

The background information of the course participants was used to find out to which profession they will be graduating or intend to apply for after graduation. Employees were asked about the current job description. Several employees had nominated many work fields for the survey, of which only the main job description was selected for the background information of this thesis. For example, when a person describes being a trainer in addition to acting as an expert, he or she was interpreted as a trainer in this context (see Table 4).

Table 5. *Future professional field of the student respondents and simplified job description of workplace employees.*

Field	CE courses	SeAMK	Workplace
Engineering	16	22	13
Technology and process development and management	8	-	2
Organization management	7	1	5
Research	7	-	-
Manufacturing management	6	-	-
Industrial design	1	4	-

Governance	1	-	-
Entrepreneur	1	-	-
Energy	1	-	-
Sustainable Building Technologies	1	-	-
Trainer/Teacher	-	1	19
Sales	-	1	15
Warehouse worker	-	-	2
Total	49	29	56

4.5 Analyses

Descriptive statistical procedures such as frequency distributions, means and standard deviations, were performed on all variables of the study and were calculated using SPSS PASW 26. The size of influence r was calculated using the formula r = z / square root of N. The background variables were analyzed using cross-tabulation. The structure of the CATS instrument was examined by separate explorative factor analyses (Maximum Likelihood, Promax rotation) of each scale as the sample size did not meet the requirements of factor analysis (see e.g., Fabrigar & Wegener, 2012). The internal consistency of the scale was examined by calculating Cronbach's Alpha values. Items dependence was analyzed using the Pearson correlation. The CATS instrument was left with an error, in which case the same statement appeared twice in the instrument. The error was corrected after nine responses. In these nine replies, answer to the statement was marked as missing.

The whole data (N = 134) were utilized in the investigation of the structure validity. In the first round, the items loaded into nine factors (see Appendix B). KMO and Barlett's Test (.904, p<.001) gave support to a correlation matrix being good for factor analysis, but Goodness-of-fit Test (Chi-Square=748.262, sig.<.001) did not support the solution. After three iterations built up final 6-factor solution. Items were removed between each iteration based on their low loading (under .40) and cross-loaded factors if the values differed by less than one. Communalities did not affect the elimination even if those values should be over 0.4 or else the item may have problems in loading into only one factor. Sixteen variables were eliminated in the iterations:

Experiential Learning

- Generating new ideas
- Hypothesis generation
- Teacher-guided discovery
- Experimentation

Discourse/Dialogic Learning
- Utilize multiple perspectives

Supportive Learning
- Process approach
- Giving feedback
- Use of imagery or visuals
- Using structured methods and frameworks
- Coaching

Critical Thinking
- Analysis
- Being critical
- Constructive argumentation / communication

Conceptual Change
- Combining ideas from different sources
- Collecting beliefs and perceptions

Self-Regulated Learning
- Personal development

KMO and Barlett's Test (.904, $p<.001$) supported the final 6-factor solution (see Table 5). The Goodness-of-fit test cannot be performed when only two items are loaded on the factor (Hair, Black, Babin and Anderson, 2010).

4.6 Ethical considerations

Invitations to participate in the survey were submitted by the teachers for students and by the training manager for employees. At least one teacher had added their own forewords to the cover letter promising extra points for the course evaluation for respondents. Making the survey mandatory may increase the response rate, but at the same time you can participate in the survey as dictated by compulsion, giving attention to the response. At the beginning of the surveys were a short introduction about the project and purpose of the survey. All surveys reported the use of responses for research purposes only, and the adherence to the ethical guidelines by The Finnish National Board on Research Integrity (TENK). All sections of the survey were required to be answered except the last section, where the informant could write feedback. As an exception, the teacher who gave the extra points had required the students to provide their email address to the feedback section in order to receive the points. The survey data were collected using the institutional system in use at the University of Helsinki (Microsoft Forms).

5 Results

The results are divided into three parts. The first part deals with the development of the instrument. The second part examines the cognitive affordances of learning categories achieved by different groups, and the last part includes a compilation of the main results.

5.1 The reliability and validity of the CATS instrument

5.1.1 The structure of the CATS instrument

The structure of the new CATS instrument resulted in a 6-factor solution. Three categories remained under the same names with the original CATS instrument: *Self-Regulated Learning*, *Discourse/Dialogic Learning* and *Learn by Doing.* Three new categories were named *Inquiry-Based Learning, Real-Life Work Situations* and *Utilize New Ideas (see Table 5).* Categories were labeled based on the key variables with the highest factor loadings or by defining a top concept describing all items in the category. Overall, a common nominator for the names of the categories was to consider the instrument as a coherent whole.

Table 6. *The 6-factor solution of CATS instrument (27 items).*

Items	F1	F2	F3	F4	F5	F6	h^2
Self-Regulated Learning (F1)							
Time management	.89						.78
Creating strategies	.89						.74
Self-evaluation	.88						.64
Self-motivation	.77						.62
Setting goals	.75						.70
Self-monitoring	.69						.46
Motivating others	.55						.59
Inquiry-Based Learning (F2)							
Inquiring information and knowledge from different sources		.84					.65
Searching information		.73					.63
Independent thinking and understanding		.65					.43
Exploration, finding different solutions		.59					.51
Problem solving		.55					.50
Developing solutions for problems		.47					.52
Real-Life Work Situations (F3)							
			.94				.80

Working in certain situations							
Creating concrete outputs, such as products or services			.78				.68
Working in certain task-related locations		-.31	.68				.58
Taking different roles			.53				.38
Decision making			.51				.70
Discourse/Dialogic Learning (F4)							
Collaboration				.91			.76
Presenting to audiences				.72			.58
Oral and written communication				.67			.57
Organizing work	.31			.65			.63
Explaining				.57			.60
Learn by Doing (F5)							
Hands on work					1.00		.99
Learning by doing					.71		.70
Utilize New Ideas (F6)							
Adapting and applying new ideas into practice						.75	.88
Presenting new ideas with practical examples						.75	.68
Eigenvalue	6.31	5.99	1.86	1.42	0.90	0.80	
% of Variance explained	23.37	22.18	6.88	5.24	3.33	2.96	
Cumulative % of Variance explained	23.37	45.55	52.43	57.67	61.00	63.96	

Self-Regulated Learning category remained largely the same as the original. Only one original item was left out of the category, making the category seven items in size. It is the broadest category by item number in the new CATS. Its label describes all items of the category.

Inquiry-Based Learning was a new category whose items relate to information retrieval and processing towards the formation of a solution. The category has six items from three different original categories. It was labeled based on the strongest loaded items which are inquiring information and knowledge from different sources and searching information. The item independent thinking and understanding was not in the original CATS but was added during the development phase of the instrument.

Real-Life Work Situations, a new category, models different situations from working life using five arguments from three different original categories. Its two most highly loaded items were working in certain situations and creating concrete outputs, such as products or services, on which the name of the category is based.

Discourse/Dialogic Learning describes collaboration and communication. The name of the category was kept the same as in the original CATS instrument even though it has items from two original categories. The items collaboration and presenting to audiences loaded the highest, which is the justification for the category name.

Learn by Doing has only two items from the original category by the same name. The items hands on work and learning by doing describe concrete action which associates with the category name. The latter item was not included in the original CATS but was added during the development phase of the instrument.

Utilize New Ideas also has only two items and it is a new category. Its items are from one original category, however, that category was renamed more simply because both items mention the exploration of new ideas. The items are adapting and applying new ideas into practice and presenting new ideas with practical examples.

5.1.2 Reliability of the CATS instrument

Cronbach's Alpha was calculated for the original CATS instrument and for a new 6-factor solution instrument (see Table 6 and 7). Alpha values were higher than .60 which is the limit for reliability.

Table 7. *Cronbach's Alpha of the original CATS instrument's categories.*

Scale	Items (n = 43)	Alpha
Experiential Learning	9	.80
Discourse/Dialogic Lear-ning	4	.85
Supportive Learning	7	.84
Learn by Doing	5	.83
Critical Thinking	5	.86
Conceptual Change	5	.84
Self-Regulated Learning	8	.93

Table 8. *Cronbach's Alpha of the new CATS instrument's categories (6-factor solution).*

Scale	Items (n = 27)	Alpha
Self-Regulated Learning	7	.92
Inquiry-Based Learning	6	.85
Real-Life Work Situations	5	.85
Discourse/Dialogic Learning	5	.87
Learn by Doing	2	.89
Utilize New Ideas	2	.85

Correlations were measured between the original seven categories of CATS as well as between 6-factor solutions factors (see Table 8 and 9). Correlations were slightly higher on average in the original CATS and all categories and factors correlate with each other significantly. In the original CATS, the Alpha's value would have increased to .013 if the item Experimentation had been deleted from the *Experiential Learning* category.

Table 9. *The correlations of the original CATS categories.*

Scale	1	2	3	4	5	6
Experiential Learning	1					
Discourse/Dialogic Learning	.68**	1				
Supportive Learning	.61**	.71**	1			
Learn by Doing	.57**	.55**	.51**	1		
Critical Thinking	.68**	.66**	.77**	.60**	1	
Conceptual Change	.64**	.51**	.70**	.59**	.65**	1
Self-Regulated Learning	.60**	.64**	.75**	.61**	.75**	.67**

**p < .01.

Table 10. *The correlations of the new CATS categories (6-factor solution).*

Scale	1	2	3	4	5
Self-Regulated Learning	1				
Inquiry-Based Learning	.57**	1			
Real-Life Work Situations	.58**	.48**	1		
Discourse/Dialogic Learning	.63**	.66**	.48**	1	
Learn by Doing	.47**	.43**	.51**	.48**	1
Utilize New Ideas	.52**	.38**	.60**	.40**	.35**

**p < .01.

Correlations were also examined for the original CATS by categories and for the 6-factor solution CATS by factors (see Appendix C and D). All others correlated internally except for the original category of *Experiential Learning*. The item Experimentation did not correlate with the other three statements and with two statements its correlation significance level was 0.05, while in all other items the correlation significance level was 0.01. Moreover, the argument in that category for Teacher Guided Learning did not correlate with Taking Different Roles.

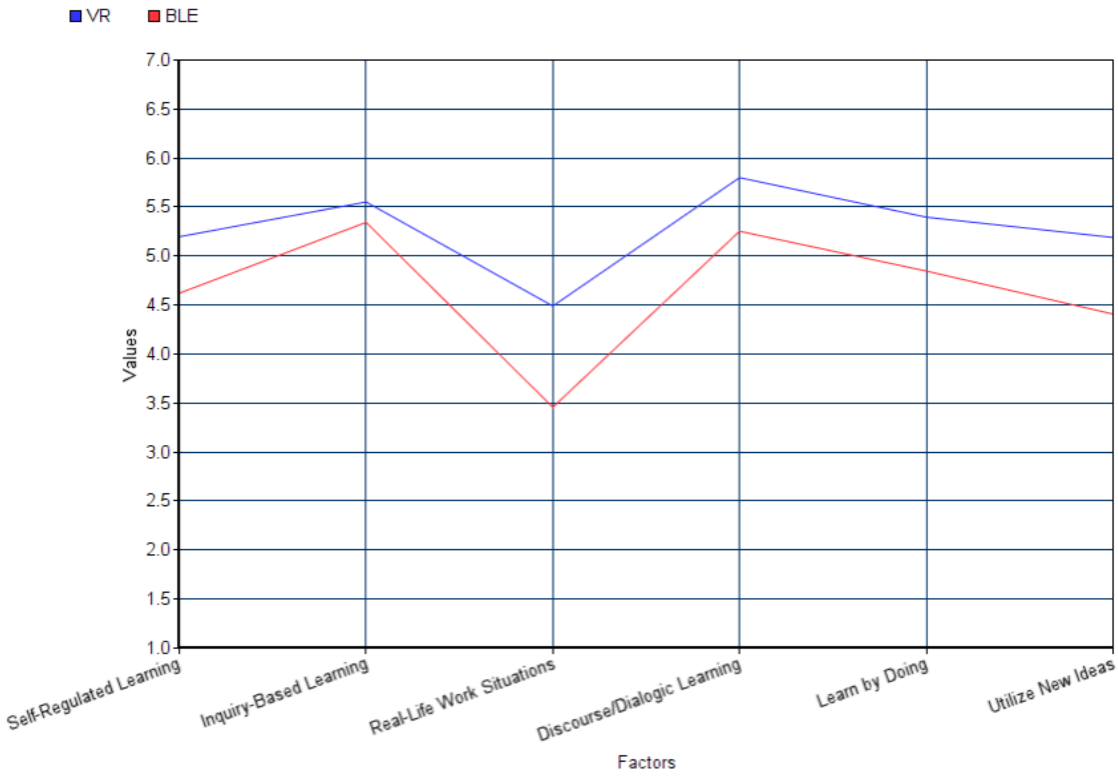
5.2 Cognitive affordances of learning in different technology-enhanced learning environments

In this section aim is to describe different profiles without comparing them directly to each other. CE courses are called blended learning (BLE) group and data of SeAMK formed to VR group. After presenting them, profiles from four different universities are described.

5.2.1 Cognitive affordances of learning in VR supported and blended learning environments

Looking at the means in Figure 6, the VR group (n = 29) had almost evenly higher mean values compared to the BLE group (n = 49). The means of both were lowest in the new category *Real-Life Working Situations* when values were in VR 4.49 and BLE 3.46. The highest means were in *Inquiry-Based Learning* and *Dialogic/Discourse Learning* factors when values were in VR 5.55 and 5.8 and BLE 5.34 and 5.25. They were categories in the original CATS instrument. Other categories were *Self-Regulated Learning*, *Learn by Doing* and *Utilize New Ideas* which have values in VR group 5.19–5.40 and BLE group 4.41–4.85.

Figure 6. *The means for the cognitive affordance factors of the BLE and VR student groups.*



The deviations of the groups are shown in Figure 7. BLE group had more deviation and the deviations of the groups decreased and increased relatively similarly. BLE group's lowest deviation were in *Inquiry-Based Learning* (.98) and highest in *Learn by Doing* (1.67). VR group's two lowest deviations were in *Inquiry-Based Learning* (.73) and *Discourse/Dialogic Learning* (.78) and two highest were *Learn by Doing* (1.36) and *Utilize New Ideas* (1.36).

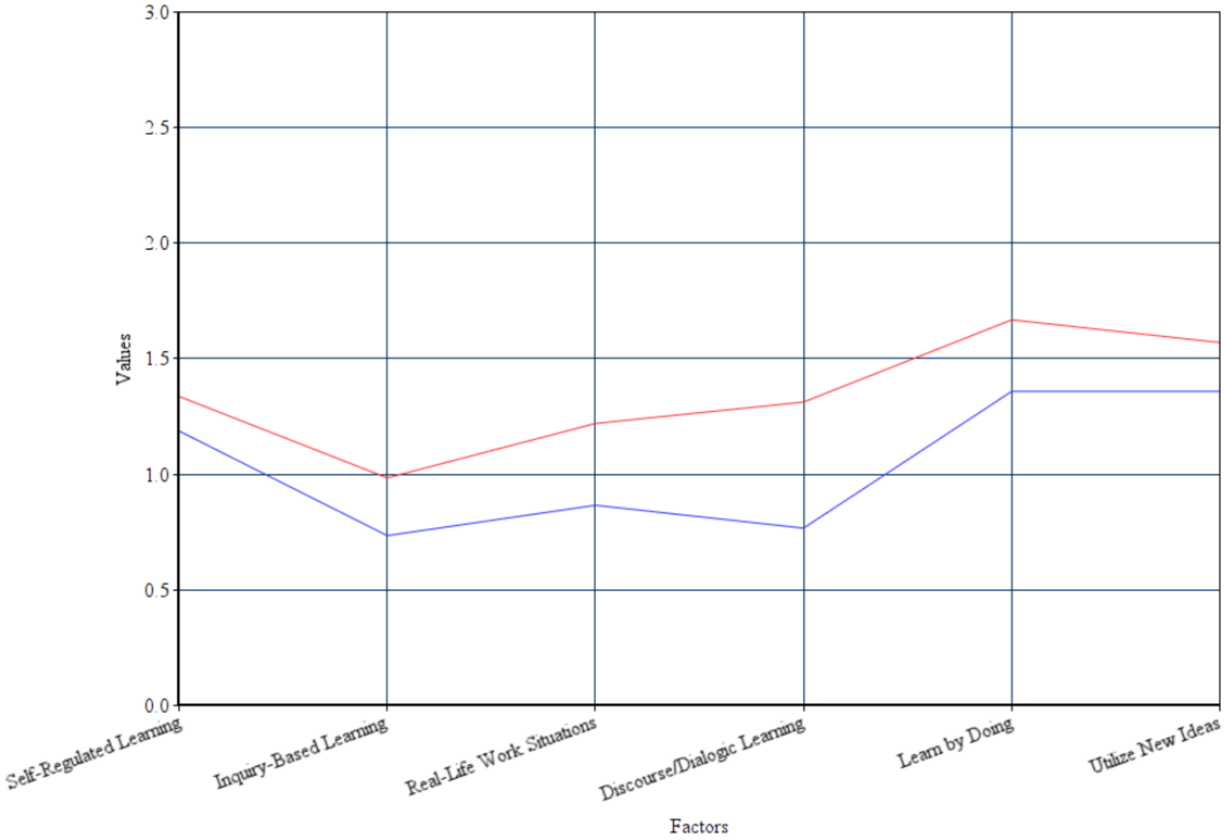


Figure 7. *The deviations for the cognitive affordance factors of the BLE and VR student groups.*

When comparing minimum and maximum values VR group had same or higher values that BLE group. Both groups have relatively high minimum values in *Inquiry-Based Learning* (VR = 4.17, BLE = 3.00). VR group have also high minimum in *Discourse/Dialogic Learning* (4.20). Maximum values were 7.00 in both groups excluding *Real-Life Work Situations* when VR had 6.80 and BLE 6.60 (see Table 10).

Table 11. *The minimum and maximum values for the cognitive affordance factors of the BLE and VR student groups.*

Scale	Minimum		Maximum	
	VR (n = 29)	BLE (n = 49)	VR	BLE

Self-Regulated Learning	1.71	1.29	7.00	7.00
Inquiry-Based Learning	4.17	3.00	7.00	7.00
Real-Life Work Situations	2.80	1.20	6.80	6.60
Discourse/Dialogic Learning	4.20	1.00	7.00	7.00
Learn by Doing	1.50	1.00	7.00	7.00
Utilize New Ideas	1.00	1.00	7.00	7.00
Avg.	2.56	1.42	6.97	6.93

5.2.2 Cognitive affordances of learning during different learning modules

BLE group was further studied during the participating universities' learning modules. Five modules were named according to the universities: LUT, DTU1, DTU2, FRA and PAD. The means of the categories of cognitive affordances provided by the environments are shown in Figure 8 and Table 12. LUT (n = 15) and DTU1 (n = 5) had same profiles with VR and BLE when categories *Inquiry-Based Learning* and *Discourse/Dialogic Learning* felt most achieved, and *Real-Life Work Situations* was achieved the least. *Real-Life Work Situations* category was also felt to be the least accessible in DTU2 (n = 9) and PAD (n = 15). Two highest categories were in DTU2 *Inquiry-Based Learning* and *Learn by Doing* and in PAD *Discourse/Dialogic Learning* and *Learn by Doing*. FRA (n = 5) differed most from the others. Its two lowest categories were *Self-Regulated Learning* and *Real-Life Work Situations*. Highest means were in *Utilize New Ideas* and *Inquiry-Based Learning*.

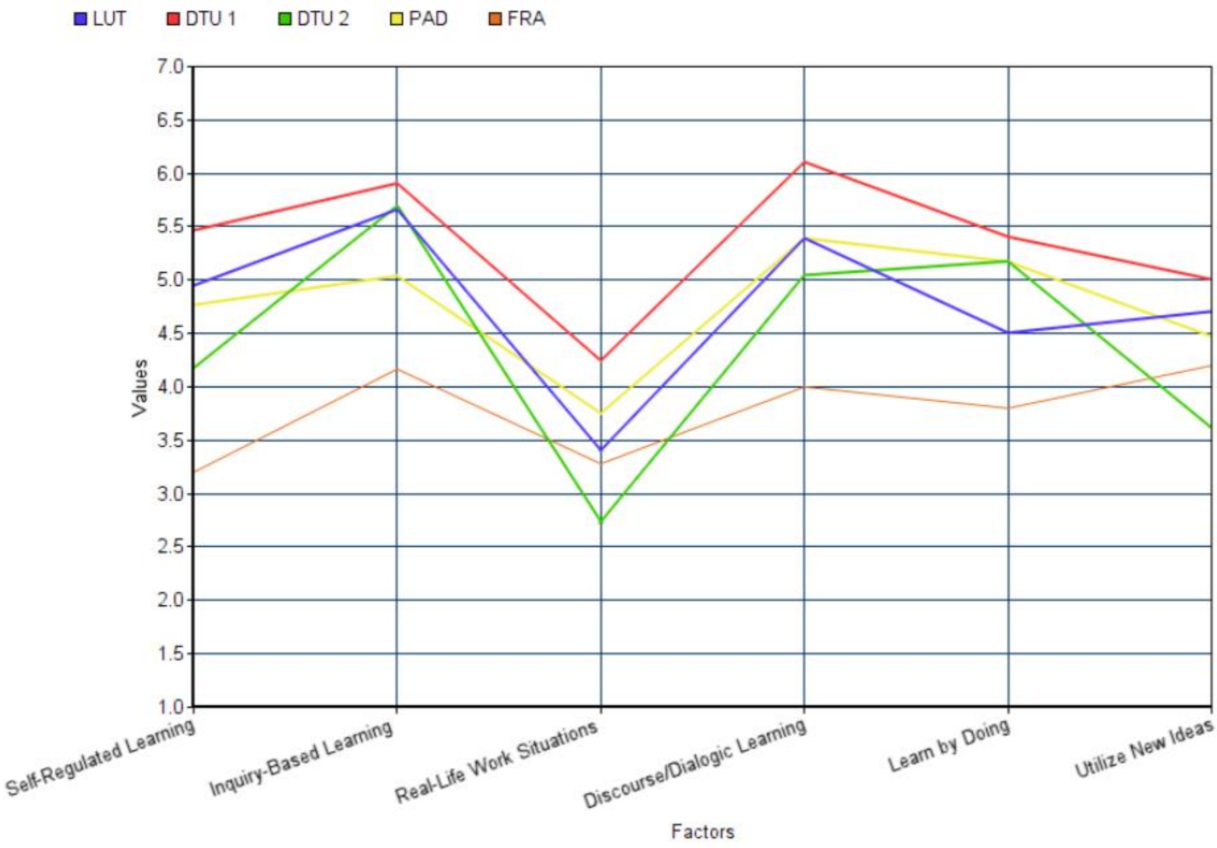


Figure 8. *The profiles based on the means of cognitive affordances factors by e-CirP courses.*

Participants from the course of DTU1 gave the highest values in average, and participants from the course of PAD gave the lowest values in average.

Table 12. *The means of the cognitive affordance factors by e-CirP courses.*

Scale	LUT (n = 15)	DTU1 (n = 5)	DTU2 (n = 9)	FRA (n = 5)	PAD (n = 15)
Self-Regulated Learning	4.94	5.46	4.17	4.76	3.20
Inquiry-Based Learning	5.66	5.90	5.69	5.03	4.17
Real-Life Work Situations	3.40	4.24	2.73	3.75	3.28
Discourse/Dialogic Learning	5.39	6.10	5.04	5.39	4.00
Learn by Doing	4.50	5.40	5.17	5.17	3.80
Utilize New Ideas	4.70	5.00	3.61	4.47	4.20
Avg.	4.77	5.35	4.40	4.76	3.78

The deviations had all the same high points in category *Inquiry-Based Learning* and low points in category *Learn by Doing* except in DTU1 and DTU2. High points were in *Utilize New Skills* in DTU1 and in *Self-Regulated Learnin*g in DTU2. Low points were in Real-Life Working Situations in DTU1 and in *Inquiry-Based Learning* in DTU2. LUT and DTU2 had larger deviation values than DTU1, FRA and PAD in every category (see Figure 9).

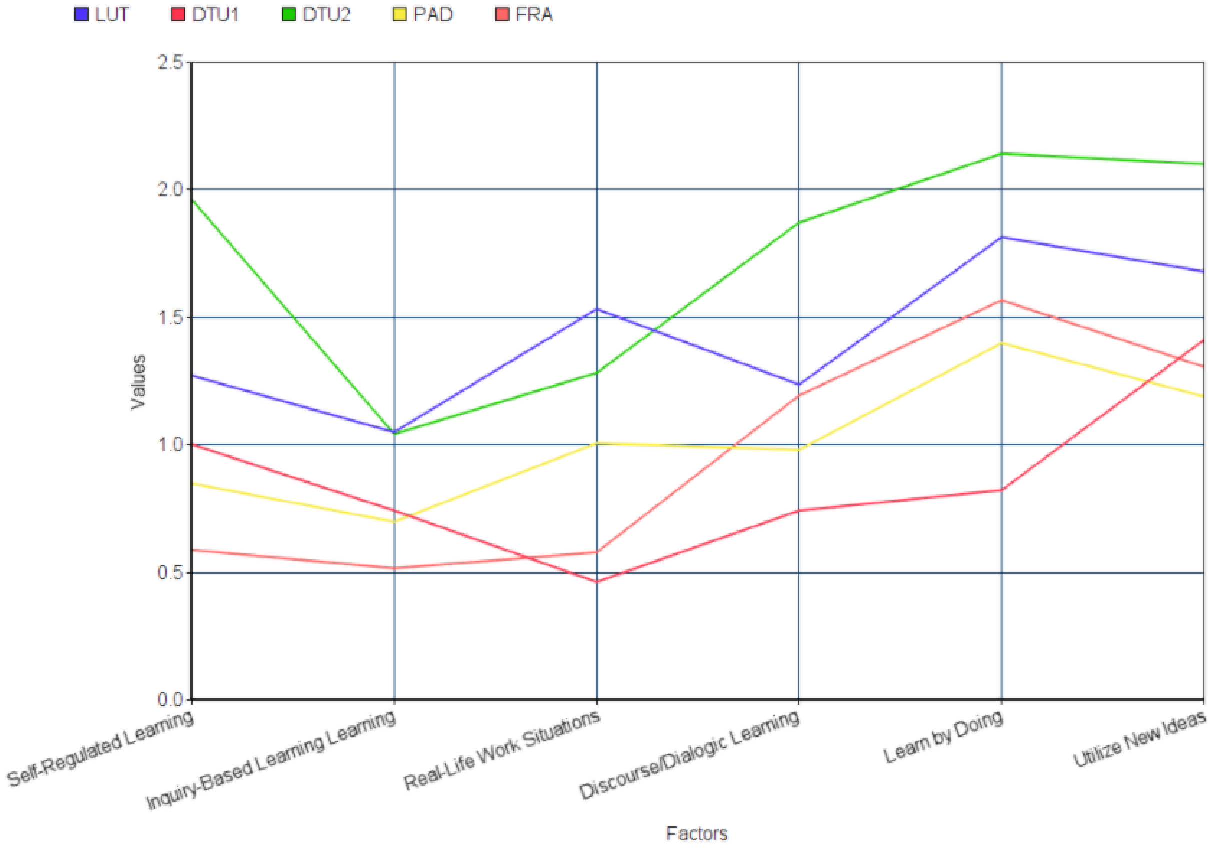


Figure 9. *The deviations for the cognitive affordance factors by e-CirP courses.*

In minimum and maximum comparison, universities do not follow any formula directly (see Table 11). DTU2 has the largest average range (1–7) and FRA has the smallest average range (2.67–5.12). All universities have given the lowest maximum value in *Real-Life Work Situations* category from 4.00 to 6.60. LUT, DTU1, DTU2 and FRA have given the highest minimum value in the *Inquiry-Based Learning* category from 3.00 to 5.00. Also, PAD have given high values to *Inquiry-Based Learning* (3.33) but it not the highest minimum.

Table 13. *The minimum and maximum values for the cognitive affordance factors by e-CirP courses.*

Scale	LUT (n = 15)	DTU1 (n = 5)	DTU2 (n = 9)	FRA (n = 5)	PAD (n = 15)	LUT	DTU 1	DTU 2	FRA	PAD
Self-Regulated Learning	2.00	4.43	1.29	2.57	3.71	6.86	7.00	5.86	4.14	6.43
Inquiry-Based Learning	3.00	5.00	3.33	3.67	3.33	7.00	7.00	6.67	5.00	6.50
Real-Life Work Situations	1.40	3.80	1.20	2.40	1.60	6.60	5.00	5.20	4.00	4.80
Discourse/Dialogic Learning	2.00	5.00	1.00	2.40	3.20	7.00	7.00	6.80	5.10	7.00
Learn by Doing	1.00	4.50	1.00	2.50	2.50	7.00	6.50	7.00	6.50	7.00
Utilize New Ideas	2.00	3.00	1.00	2.50	2.50	7.00	7.00	7.00	6.00	6.00
Avg.	1.9	4.29	1.47	2.67	2.80	6.91	6.50	6.00	5.12	6.29

5.3 Summary of the main results

Based on the whole survey data, a 6-factor solution with 27 items was constructed from the CATS instrument. Cognitive affordances of learning categories were formed into

- Self-Regulated Learning
- Inquiry-Based Learning
- Real-Life Work Situations
- Discourse/Dialogic Learning
- Learn by Doing
- Utilize New Ideas.

The two most prominent affordances of learning categories were *Inquiry-Based Learning* and *Discourse/Dialogic Learning* in the groups of VR (n = 23) and BLE (n = 49). The same result came from LUT (n = 15) and DTU1 (n = 5) universities within the BLE group. In DTU2 (n = 9) the two most significant categories were *Inquiry-Based Learning* and *Learn by doing* of which the latter also emerged in PAD (n = 15). In addition, the category *Discourse/Dialogic Learning* emerged there. In FRA (n = 15) the highest ranked categories were *Inquiry-Based Learning* and *Utilize New Ideas*. There are five to six items in the categories that emerged in the main groups (VR and BLE), while other categories that emerged have only two items (see Figure 10).

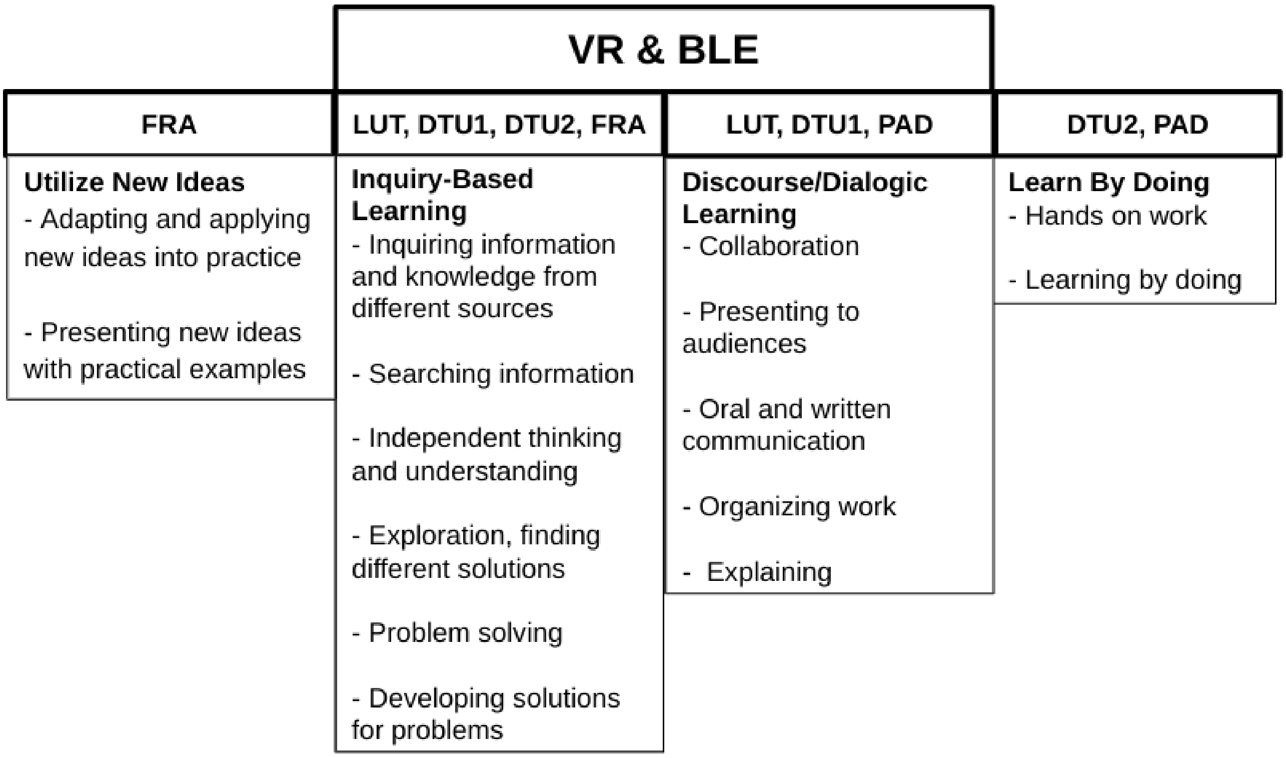


Figure 10. *The two main categories of cognitive affordances by main groups and e-CirP courses.*

6 Discussion and conclusions

This section presents the main findings of the study in the light of what can be deduced from them. Then, the reliability validity of the methodologies and limitations of the study are discussed. Finally, conclusions future research proposals and educational implications are presented.

6.1 The main findings of the study

Although this thesis cannot be directly interpreted as a repetition of the study by Dabbagh and Dass (2013), it has the same features in terms of instrument as well as groups. The results of this thesis describe different profiles. Due to the diversity of environments, a comparison of results is not statistically implemented. Instead, this thesis intends to describe what offerings were experienced in the environments, and to analyze them. The unified line also continues regarding the cognitive affordances of learning achieved by groups. In this thesis main groups were VR-enhanced learning and blended learning. Students from both environments reported the most cognitive affordances from categories *Inquiry-Based Learning* and *Discourse/Dialogic Learning.*

In the study by Dabbagh and Dass (2013), the VR group reported the most cognitive affordances from the *Experiential Learning and Learn by Doing* categories. *Experiential Learning* corresponds to a significant part to the new category of *Inquiry-Based Learning because* it has four of the six items from the original *Experiential Learning* category so in that respect the results are parallel. The category *Learn by Doing* did not emerge in the VR group of this thesis in the same way as in the study of Dabbagh and Dass (2013).

Cognitive affordances of *Discourse/Dialogic Learning* category were not reported to a high degree by the VR group in the study of Dabbagh and Dass (2013). In this thesis cognitive affordances from *Discourse/Dialogic Learning* category ranked in the top two categories by the VR group. The differences between VR groups from this thesis and Dabbagh and Dass (2013) can be explained by the fact that the VR context of this thesis includes, in addition to VR, group discussion after VR.

As previously assumed, the blended learning group as non-VR group reported cognitive affordances from the Dialogic/Discourse Learning category as in the study by Dabbagh and Dassin (2013). In this thesis, however, a new category, *Inquiry-Based Learning*, emerged alongside that category. The differences between this thesis and the study by Dabbagh and Dass (2013) are probably explained at least by the technology contained in blended learning, which was not present in the original non-VR group.

Emerging cognitive affordances were also examined within the blended learning group by course. In addition to the categories that emerged in the main group results, the categories *Utilize New Ideas* and *Learn by Doing* emerged in the three courses. These categories have only two items while *Inquiry-Based Learning* and *Discourse/Dialogic Learning* categories have five to six items. Due to the small number of items, they cannot function as separate categories in further research but require new items (see section 6.2).

In all groups, cognitive affordances from the *Real-Life Work Situations* category were among the least or second least achieved. It was a new category, and it has five items. The challenge in achieving cognitive affordances from that category may have been the challenge of implementing education that is related to real working life, or inaccurate descriptions of items. In addition, there were large differences in minimum and maximum values between courses, which can be explained by small numbers of respondents and different courses.

6.2 Reliability of the study

Design science research (DSR) was chosen as the methodological approach of this thesis. The goal was to implement the first cycle in piloting a CATS instrument as a self-reporting tool for a survey. As its name implies, the Design Science Research Cycle model (Hevner, 2007, p. 88) consists of cycles, for which this thesis only presents the initial setups and the first steps in the development of an instrument towards survey research and for measuring technology-enhanced learning. The model created a clear basis for conducting the study and evaluating it.

As stated in the first DSR model (see Figure 5), the challenge of the study was a medium sized data set consisting of several groups. However, the diversity of the groups amounted to new results about the possible parallel benefits of blended learning and VR. Of course, the similar results of the groups should not come as a surprise, because VR-enhanced learning can be seen a part of the blended learning concept. Here, however, it was intended to be distinguished from other blended learning in order to find out the potential benefits of VR that other technological solutions do not offer.

The second DSR model (see Figure 11) presents the implementation of Design Science Research Cycles in this study. The Relevance Cycle includes CATS instruments pilots for this study as well as this thesis, which can be understood as a broader pilot. Rigor Cycle highlights the problematic nature of the concept of cognitive affordance and includes a new version of the CATS instrument formed in this thesis. Finally, Design Cycle resulted in changes to the instrument and evaluation of the results obtained.

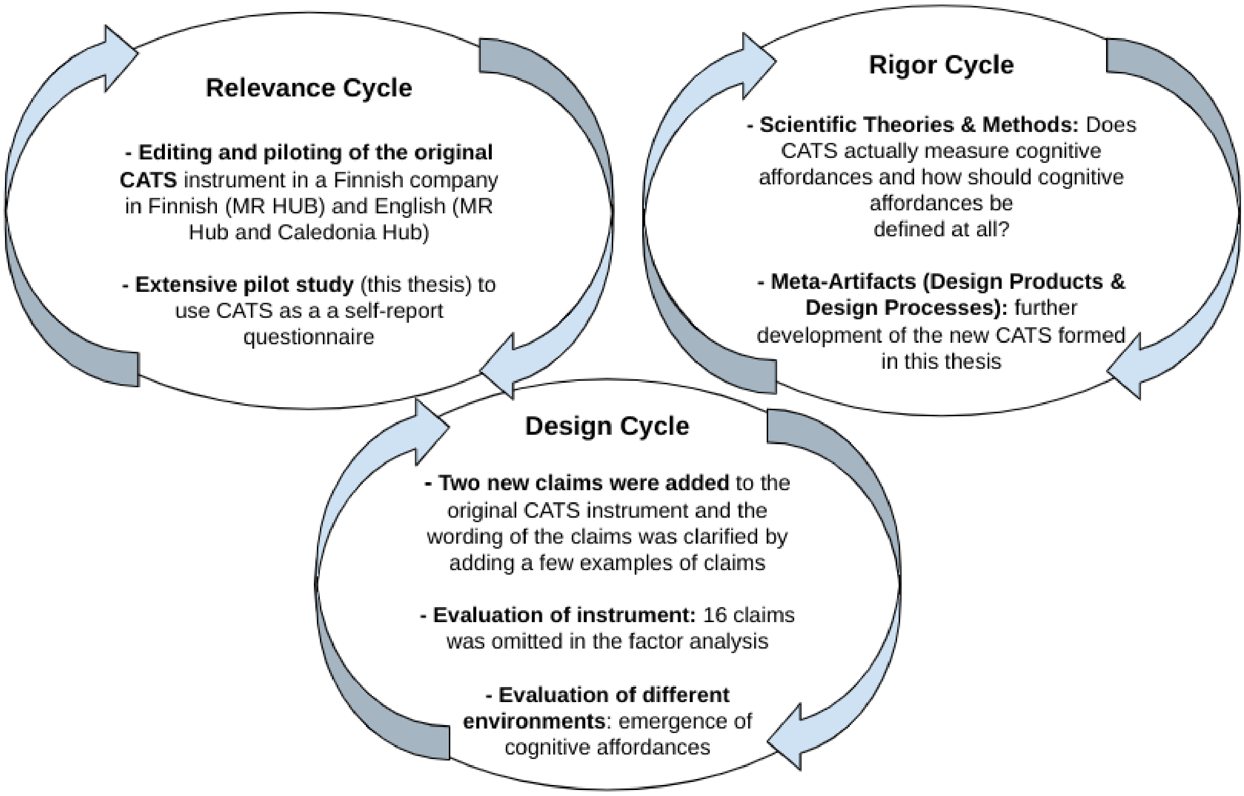


Figure 11. *Realization of Design Science Research Cycles in this thesis (based on Hevner, 2007, p. 88).*

The CATS instrument contains cognitive affordances of learning (Dabbagh, Conrad & Dass, 2010; Dabbagh & Dass, 2013), which are offerings in the environment that everyone interprets from their own perspective and culture (Zang and Patel, 2006). However, the definition of cognitive affordance is not entirely explanatory. Based on the literature, there are more similar concepts such as educational affordance (Kirshner, 2002) and it is possible to interpret items of the CATS instrument as belonging to other categories of affordances than cognitive affordances (Hartson, 2003; Kreijns, Kirschner & Jochems, 2002; Zang & Patel, 2006). When comparing the items of the CATS instrument, for example to the affordance categories of Zang and Patel (2006), the affordances of CATS would belong to the mixed affordance section, which combines another affordance category in addition to the cognitive affordance. Such could be, for example, affordances from *Learn by Doing* category, which combines physical affordance with cognitive affordance.

In section 2.4, the list for the development of a standardized measurement instrument was presented (Crocker and Algina, 1986 as cited in Liu, 2010). The same listing from the perspective of this thesis is presented below.

1. This thesis seeks to explore the cognitive affordances of learning that different technology-enhanced learning environments offer to their users in from the view of participants.
2. Categories of the original CATS instrument e.g., experiential learning (see section 2.2.2).
3. Items of the original CATS instrument (see section 2.2.2).
4. Items of the original CATS instrument (see section 2.2.2).
5. Modifying the items of the original CATS instrument to fit a self-report survey (see section 4.3).
6. Pilot tests and item modifications by the research teams (see section 4.3).
7. Study of this thesis.
8. Factor analysis and excluding items which did not meet the criteria in sections 4.5 and 5.1.
9. In this thesis e.g., Cronbach Alpha (see section 5.1).
10. Theoretical framework (see section 2) consist base for the interpreting results and the analysis of the results can be found in section 6.

In the factor analysis, 16 items were removed from the CATS instrument based on factor loading. Deletion was done manually based on values. Arguments that could possibly be removed with different material could have deviated from this thesis. Two-item factors emerged that are not as such functional in further testing of the new instrument. To these should be added a few arguments which support the unity of the category. For example, items like c*oncrete doing* or l*earning by experiment* could fit into the *Learn by Doing* category and items like *combining new ideas* or *developing new ideas* could fit into the *Utilize New Ideas* category.

6.3 Validity of the study

Assessing the validity of the study began when the development of a suitable version of the CATS instrument for the survey was formulated in the research groups. The setting of hypotheses was part of the construct validity. For the first hypothesis, the number and structure of subscales were not kept. As a result of the factor analysis, a new version of the CATS instrument containing six subscales was formed. However, it had many similarities to the structure of the original instrument in terms of categories. For example, in total, three original category names were retained, and three new ones were formed. The Self-Regulated Learning category differed from its predecessor only in containing one item less but was otherwise identical in content. Learn by Doing and Utilize New Ideas contained items from only one original category, the name of which remained the same for Learn by Doing.

The second hypothesis assumed that the instrument was suitable for finding differences in the achievement of cognitive affordances in different environments, which was not the case. BLE and VR environments probably have too many similar features, such as leveraging technology and group discussions. Dabbagh and Dass (2013) got differences between the traditional learning environment and the VR-enhanced environment, but the traditional environment did not utilize technology at all. However, for the second hypothesis, the old category *Experiential Learning* being now *Inquiry-Based Learning* category was reported to offer cognitive affordances by the VR group successfully. The blended learning group also reached the hypothesis assigned to it, that of *Discourse/Dialogic Learning*. In addition, the groups reached out to each other in the achievable affordance category. This could indicate a similarity of the groups mentioned above.

For construct validity to be realized, the correlation should be stronger between similar concepts compared to others (Metsämuuronen, 2006). In the new CATS instrument, there was largely a significant correlation within the categories that could indicate the functionality of the categories. However, there was a strong correlation between the categories when comparing both the original and the new CATS instrument, which in turn highlights the excessive similarity of the categories. In the new CATS instrument, the correlations between the categories were lower than in the original, which may indicate the right way for developing the instrument.

The structure validity reflects the extent to which the structure of the instrument explains the results (Scholtes, Terwee & Poolman, 2011). Considering the KMO and Barlett's Test as well as the factor loads, the structure of the new CATS instrument was functional. A comparison of values obtained in different contexts but with the same instrument is given by criterion validity (Metsämuuronen, 2006). When considering an instrument's reliability, high Cronbach's Alpha values and results pointed towards the instrument's reliability. The average value of the Likert scale can be interpreted not only as a neutral opinion, but also as an argument that one cannot comment on an argument (Ronkainen, Mertala & Karjalainen, 2008). In this thesis it was interpreted as the mean value.

At least one teacher promised to give additional points for the course evaluation if student answers to the CATS survey. However, it can be assumed that this did not affect the validity of the responses, as has been shown by e.g. Singer and Kulka (2002), and had little or no marked effects on the sample composition (Göritz, 2004).

As noted above, the same cognitive affordances were reported in this thesis context in the blended learning and VR-enhanced learning. The reason for similar outcomes may be the similarity of the learning environments. Based on the literature, VR can be interpreted as part of blended learning. For example, according to a definition of Driscoll (2002), blended learning can mean the use of virtual technology in teaching. His definition of combining technology with face-to-face teaching and combining technology with working life skills also support the interpretation. In addition, based on Allan (2007), VR can be interpreted as part of blended learning, because blended learning is a holistic approach to learning which includes real and virtual aspects.

6.4 Limitations of the study

This thesis was a pilot study with a smaller than expected response population. The courses were new so the number of participants could not be predicted. This shortcoming was compensated by taking supportive data from another context. Unlike working life data, Seamk data was not for a substitute, but for comparison.

In the background information, it would have been useful to gather more detailed information about the technologies used in the courses as well as the teaching methods offered, such as group work. In general, it is a good idea to utilize several researchers in the analysis of the data, in which case cross-analysis would minimize, for example, individual typing errors and other human errors. Small and different groups did not allow for comparison of groups but allowed for the presentation of different profiles.

In further research, triangulation should be utilized in the selection of research methods, so that the phenomenon can be studied from several perspectives at the same time (Thurmond, 2001). For example, the interview data could describe how the statements in the survey were concretely reflected in the courses and whether the items were interpreted in the same way. This thesis was intended to utilize interviews in addition to the survey, but not enough interviewees got involved. The involvement of teachers working in the field should be considered where possible in order to collect the material more widely.

6.5 Conclusions, further research and educational implications

The CATS instrument was originally developed for an observational study, but after the pilot period, no further study can be found. In this thesis the CATS instrument was developed and applied to use as a self-report instrument for survey research, because of the nature of cognitive affordances. Everyone interprets cognitive affordances from their own perspective (Zang and Patel, 2006). This thesis described students 'experience of the cognitive affordances achieved by technology-enhanced learning environments. In a previous study, a comparison had been made between a VR-only learning environment and a completely non-technological environment. However, this comparison no longer makes sense today, when utilization of technology is a dominant part of working life as well as learning for example in the form of distance learning and working.

In the future, it is worth exploring the possibilities of different technologies more widely, such as VR, AR or computer. If possible, it is also worth getting to know the differences between the different VR user interfaces to find out what kind of technology is worth investing in education. The study of Dabbagh and Dass

(2013) used two-dimensional computer VR while the VR of this thesis was used via head-mounted display. In addition, other solutions used in the courses related to the implementation of teaching could be opened more in the background information such as group discussions, lectures and group assignments. The effect of background variables was not addressed in the analysis of this thesis as they were not considered to add value to the review.

Education should prepare for future working life skills by “practicing collaborative problem-solving and teamwork through hands-on projects within and beyond the classroom" (OECD, 2019, p. 102). The CATS instrument aims to find out if education enable achieve the skills required in working life (Dabbagh & Dass, 2013). Items should describe the skills required in working life, and if compared to the above OECD (2019) description, the CATS instrument contains the similar items such as hands on work, collaboration, problem solving, working in certain task-related locations and situations (Dabbagh, Conrad & Dass, 2010). Overall, the development of the CATS instrument should be continued by stabilizing the structure of the instrument in the context of course development.

This thesis is based on the belief that learning environments include and will increasingly include a variety of technologies that should be learned to utilize in contexts appropriate to the potential offered by technology. The different potentials of different technologies should be presented in more detail in the initial and in-service training of classroom teachers, so that they can be used in the right situations as part of teaching. Based on the results of this thesis, blended learning and virtual reality -enhanced learning environments allowed participants to achieve similar cognitive affordances. However, it is not possible to say whether this is due to technologies but may be due to, for example, similar teaching cultures. Overall, the affordances have been studied quite a bit in the learning environments as actual affordances. Exploring the learning environments by affordances could clarify the roles of different technologies in learning environments in future research.

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Appendices

Appendix A. Differences in items of the versions of the CATS instrument.

Original	e-CirP	SeAMK
Experiential Learning		
Problem Solving	Problem solving	Ongelmanratkaisukykyä
Hypothesis Generating	Hypothesis generation	Ratkaisuvaihtoehtojen esittämistä
Exploration	Exploration, finding different solutions	Ratkaisuvaihtoehtojen etsimistä
Role Playing	Taking different roles (e.g., salesperson, service technician, manager etc.)	Eri roolien ottamista, esim. myyjä, huoltomies, siivooja tms.
Generate New Ideas	Generating Hypothesis (answers 1-9) Generating new ideas	Uusien ideoiden kehittelyä
Experimentation	Experimentation	Kokeiden ja koeasetelmien tekemistä
(Not in the original)	Independent thinking and understanding	Asioiden oivaltamista itsenäisesti
Teacher-Guided Discovery	Teacher-guided discovery	Asioiden oivaltamista tuettuna, ts. apua ja tukea saatavilla
Inquiry-Based	Inquiring information and knowledge from different sources	Asioiden tiedustelua eri lähteistä
Discourse/Dialogic Learning		
Collaboration	Collaboration	Yhteistyötä
Reflection	Presenting to audiences	Asioiden esittämistä käytännön esimerkkien avulla
Multiple Perspectives	Utilize multiple perspectives	Asioiden tarkastelua eri näkökulmista
Articulation	Oral and written communication	Suullista kommunikointia
Supportive Learning		
Coaching	Coaching	Valmentamista
Scaffolding	Process approach	Vaiheittain etenemistä (pitkäjänteisyyttä)
Modeling	Using structured methods and frameworks	Jäsentelyä, ts. asioiden asettamista viitekehyksiin
Explaining	Explaining	Asioiden selittämistä
Feedback	Giving feedback	Palautteen antamista
Task Breakdown	Organizing work	Tehtävien jäsentelyä
Imagery or Visuals	Use of imagery or visuals	Kuvien ja kuvaajien käyttöä
Learn by Doing		
(Not in the original)	Learning by doing	Käytännönosaamista, ts. opeteltua ammattitaitoa
Personally Relevant	Hands on work	Konreettista asioiden tekemistä ja suorittamista
Authentic	Working in certain task-related locations (physical facilities)	Tietyissä paikoissa työskentelyä (fyysiset tilat)
Context / Situated	Working in certain situations (different recurring situations, client encounter, negotiations, etc.)	Tietyissä tilanteissa työskentelyä (erilaiset toistuvat tilanteet, esim. asiakkaan kohtaaminen, neuvotelut jne.)
Build Artifacts	Creating concrete outputs, such as products or services	Konkreettisia tuotoksia, esim. tuotteita tai palveluita

Critical Thinking		
Decision Making	Decision making	Päätöksentekoa
Analysis	Analysis	Analyyttisyyttä
Synthesis	Developing solutions for problems	Synteesien tekemistä, ts. asioiden ja ratkaisujen yhdistämistä
Critique	Being critical	Kriittisyyttä
Construct an Argument / Argumentation	Constructive argumentation / communication	Rakentavaa argumentointia/ kommunikointia
Conceptual Change		
Elicit Prior Knowledge, Beliefs, and Perceptions	Searching for information	Tiedon hankkimista
Bridge Current Idea to Normative or New Ideas	Collecting beliefs and perceptions	Uskomuksien ja käsityksien keräämistä
Pivotal Cases	Combining ideas from different sources	Ideoiden yhdistämistä
Anchoring Experiences	Presenting new ideas with practical examples	Uusien ideoiden esittämistä käytännön esimerkkien avulla
Transfer	Adapting and applying new ideas into practice	Uusien ideoiden muokkaamista ja soveltamista käytäntöön
Self-Regulated Learning		
Promote Metacognition in Students	Personal development	Oman toiminnan kehittämistä
Goal Setting	Setting goals	Tavoitteiden asettelua
Task Strategies	Creating strategies	Strategioiden luomista
Time Management	Time management	Ajanhallintaa
Motivation - Intrinsic	Self-motivation	Itsensä motivointia
Motivation - Extrinsic	Motivating others	Muiden motivointia
Self-Monitoring	Self-monitoring	Itsensä ja oman työnsä tarkkailua, ts. kirjanpitoa omasta työstä
Self-Evaluation	Self-evaluation	Itsensä ja oman työnsä arviointia, ts. analyysiä onnistumisista ja epäonnistumista

Appendix B. The 9-factor solution of CATS instrument (43 items).

	F1	F2	F3	F4	F5	F6	F7	F8	F9	*h²*
F1										
7 Time management	.87									.75
7 Self-motivation	.83									.66
7 Self-evaluation	.83									.63
7 Creating strategies	.82									.78
7 Self-monitoring	.80									.53
7 Setting goals	.66							.38		.80
7 Personal development	.51					-.46				.90
7 Motivating others	.49									.66
F2										
1 Inquiring information and knowledge from different sources		.87								.69
6 Searching for information		.77								.68
1 Independent thinking and understanding		.67								.45
1 Problem solving		.59								.50
1 Exploration, finding different solutions		.55								.53
5 Developing solutions for problems		.49								.60
1 Generating new ideas		.36								.41
F3										
4 Working in certain situations			.89							.79
4 Creating concrete outputs, such as products or services			.78							.68
4 Working in certain task-related locations			.60							.60
1 Taking different roles			.54							.40
5 Decision making			.52							.75
3 Coaching			.45		.41					.83
F4										
2 Collaboration				.79						.80
2 Presenting to audiences				.69						.61
2 Oral and written communication				.61						.58
3 Organizing work				.45		.31		.38		.71
3 Explaining				.41		.34				.66
1 Teacher-guided discovery		.31		.39					.35	.50
F5										
					.86					.76

6 Presenting new ideas with practical examples										
6 Adapting and applying new ideas into practice			.36		.79				.34	.92
6 Collecting beliefs and perceptions					.39					.47
6 Combining ideas from different sources	.31	.34			.38					.57
1 Experimentation					.34					.28
F6										
3 Using structured methods and frameworks						.73				.53
3 Process approach			.31			.40				.59
F7										
4 Hands on work							1.03			1.00
4 Learning by doing							.71			.71
F8										
5 Constructive argumentation / communication								.53		.66
3 Giving feedback				.30				.50		.70
5 Being critical						.30		.41		.54
5 Analysis								.39		.64
3 Use of imagery or visuals					.31			.34		.51
F9										
1 Hypothesis generation									.59	.49
2 Utilize multiple perspectives									.31	.71

Appendix C. Correlations between original CATS instruments items by category.

Experiential Learning	PS	HG	EXPL	TD	GN	EXPE	IT	TG
Problem solving (PS)	1							
Hypothesis generation (HG)	.28**	1						
Exploration (EXPL)	.52**	.44**	1					
Taking different roles (TD)	.33**	.29**	.27**	1				
Generating new ideas (GN)	.32**	.30**	.51**	.35**	1			
Experimentation (EXPE)	-.03	.22*	.14	.27**	.43**	1		
Independent thinking and understanding (IT)	.34**	.36**	.43**	.24**	.43**	.22*	1	
Teacher-guided discovery (TG)	.32**	.50**	.37**	.12	.33**	.19*	.44**	1
Inquiring information and knowledge from different sources	.45**	.30**	.52**	.25**	.41**	.09	.54**	.51**
Discourse/Dialogic Learning	C	PA	UM					
Collaboration (C)	1							
Presenting to audiences (PA)	.65**	1						
Utilize multiple perspectives (UM)	.59**	.50**	1					
Oral and written communication	.64**	.61**	.50**					
Supportive Learning	C	PA	US	E	GF	OW		
Coaching (C)	1							
Process approach (PA)	.50**	1						
Using structured methods and frameworks (US)	.26**	.44**	1					
Explaining (E)	.48**	.54**	.44**	1				
Giving feedback (GF)	.52**	.39**	.34**	.51**	1			
Organizing work (OW)	.39**	.48**	.44**	.62**	.66**	1		
Use of imagery or visuals	.28**	.33**	.36**	.39**	.49**	.52**		
Learn by Doing	LD	HW	WCT	WCS				
Learning by doing (LD)	1							
Hands on work (HW)	.81**	1						
Working in certain task-related locations (WCT)	.42**	.51**	1					
Working in certain situations (WCS)	.37**	.37**	.61**	1				
Creating concrete outputs	.33**	.32**	.47**	.73**				
Critical Thinking	DM	A	DS	BC				
Decision making (DM)	1							
Analysis (A)	.63**	1						
Developing solutions for problems (DS)	.55**	.61**	1					
Being critical (BC)	.43**	.53**	.57**	1				
Constructive argumentation / communication	.54**	.62**	.50**	.50**				
Conceptual Change	SI	CB	CI	PN				
Searching for information (SI)	1							
Collecting beliefs and perceptions (CB)	.45**	1						
Combining ideas from different sources (CI)	.48**	.54**	1					
6 Presenting new ideas with practical examples (PN)	.43**	.45**	.52**	1				
6 Adapting and applying new ideas into practice	.38**	.56**	.51**	.75**				
Self-Regulated Learning	PD	SG	CS	TM	SMOT	MO	SMON	
7 Personal development (PD)	1							

7 Setting goals (SG)	.75**	1					
7 Creating strategies (CS)	61**	.72**	1				
7 Time management (TM)	.66**	.73**	.73**	1			
7 Self-motivation (SMOT)	.65**	.59**	.67**	.67**	1		
7 Motivating others (MO)	.62**	.62**	.60**	.63**	.67**	1	
7 Self-monitoring (SMON)	.50**	.52**	.56**	.57**	.55**	.45**	1
7 Self-evaluation	.54**	.65**	.63**	.69**	.60**	.61**	.62**

*$p < 0.05$.

**$p < 0.01$.

Appendix D. Correlations between 6-factor solution of CATS instruments items by factors.

Self-Regulated Learning	TM	CS	SE	SMOT	SG	SMON
7 Time management (TM)	1					
7 Creating strategies (CS)	.74**	1				
7 Self-evaluation (SE)	.69**	.63**	1			
7 Self-motivation (SMOT)	.67**	.67**	.60**	1		
7 Setting goals (SG)	.73**	.72**	.65**	.59**	1	
7 Self-monitoring (SMON)	.53**	.56**	.62**	.55**	.52**	1
7 Motivating others	.63**	.60**	.61**	.67**	.62**	.45**
Inquiry-Based Learning	II	SI	IT	E	PS	
1 Inquiring information and knowledge from different sources (II)	1					
6 Searching for information (SI)	.62**	1				
1 Independent thinking and understanding (IT)	.54**	.52**	1			
1 Exploration (E)	.52**	.53**	.43**	1		
1 Problem solving (PS)	.45**	.53**	.34**	.52**	1	
5 Developing solutions for problems (DS)	.46**	.50**	.46**	.48**	.48**	
Real-Life Work Situations	WCS	CC	WCT	TD		
4 Working in certain situations (WCS)	1					
4 Creating concrete outputs (CC)	.73**	1				
4 Working in certain task-related locations (WCT)	.61**	.47**	1			
1 Taking different roles (TD)	.53**	.52**	.41**	1		
5 Decision making	.66**	.63**	.44**	.43**		
Discourse/Dialogic Learning	C	PA	OWC	OW		
2 Collaboration (C)	1					
2 Presenting to audiences (PA)	.65**	1				
2 Oral and written communication (OWC)	.64**	.61**	1			
3 Organizing work (OW)	.58**	.51**	.49**	1		
3 Explaining	.62**	.51**	.60**	.62**		
Learn by Doing	HW					
4 Hands on work (HW)	1					
4 Learning by doing	.81**					
Utilize New Ideas	AA					
6 Adapting and applying new ideas into practice (AA)	1					
6 Presenting new ideas with practical examples	.75**					

**p < .01.