Virtual reality supporting cooperative learning and relatedness

Students' experiences in two learning settings

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Objectives. Virtual reality has gained a lot of interest with its new possibilities for teaching and learning, but research has focused on usability rather than lesson designs that support learning. The aim of this study is to examine how the elements of cooperative learning and relatedness are supported in a student group learning with one pair of VR headset. The study compared students' experiences with a conventional workshop lesson and a lesson with a VR learning tool.

Methods. The participants of this study were forestry students (*N*=35) both in upper secondary and higher education. Mixed methods were used, and data were collected using semi-structured thematic interviews and electronic surveys. The data consisted of two group interviews and one pair interview, as well as data from four surveys from each participant. The data were analysed with theory-driven thematic analysis and nonparametric quantitative methods.

Results and conclusions. The results of this study showed that cooperative learning was less experienced in the lesson with a VR learning tool than in the lesson with a physical machine. VR tool was seen to encourage more individual work and decreasing communication between the user and the peers, negatively affecting the positive interdependence and promotive interaction between group members. The results also suggested that experiences of relatedness became stronger when changing from VR lesson to workshop and weakened when changing from workshop to VR, though these results were not statistically significant. The findings suggest that experiences with VR might be more positive when the tool is used as an introduction to a new topic in the studies. When cooperative learning of students is pursued, it is suggested that more focus should be laid on supporting positive interdependence and promotive interaction in a lesson design with a VR tool.

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oppiminen, virtuaalitodellisuus, yhteistoiminnallinen oppiminen, yhteenkuuluvuuden tunne

Keywords
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Tavoitteet. Virtuaalitodellisuus on herättänyt paljon kiinnostusta uudenlaisena oppimisen ja opettamisen työkaluna, mutta tutkimus on painottunut enimmäkseen käytettävyyden tutkimiseen eikä oppimista tukevien opetusratkaisujen tutkimiseen. Tämän tutkimuksen tavoitteena oli tutkia kuinka hyvin yhteistoiminnallisen oppimisen elementtejä ja yhteenkuuluvuuden tunnetta voidaan tukea oppitunnilla, jossa käytetään oppimisvälineenä yksiä VR-laseja. Tässä tutkimuksessa vertailtiin opiskelijoiden kokemuksia oppitunnilla, jossa käytettiin virtuaalilaseja ja virtuaalimaailmaa näyttävää näyttöä työpajaoppituntiin, jossa opiskeltiin oikean laitteen äärellä.

Menetelmät. Tämän tutkimuksen osallistujina oli toisen ja korkea-asteen metsäalan opiskelijoita (*N* = 35). Tutkimus oli monimenetelmällinen, ja tutkimusaineistoa kerättiin puolistrukturoiduilla teemahaastatteluilla ja sähköisellä kyselylomakkeella. Aineisto sisälsi kaksi ryhmähaastattelua ja yhden parihaastattelun, sekä neljän kyselylomakkeen vastaukset kaikilta osallistujilta. Aineisto analysoitiin teorialähtöisellä sisällönanalyysilla ja ei-parametrisilla kvantitatiivisilla testeillä.

Tulokset ja johtopäätökset. Tässä tutkimuksessa havaittiin, että yhteistoiminnallista oppimista koettiin vähemmän oppitunnilla, jossa käytettiin VR-työkalua. VR-työkalun koettiin kannustavan enemmän yksilökeskeiseen työskentelyyn ja heikentävän kommunikaatiota opiskelijoiden välillä, mikä heikentää positiivista keskinäistä riippuvuutta ja vuorovaikutteista viestintää. Tutkimustulokset viittasivat myös siihen, että yhteenkuuluvuuden tunteen kokemus vahvistui siirryttäessä VR-oppitunnilta työpajaan ja heikentyi työpajatunnilta siirryttäessä VR-oppitunnille, vaikkakin nämä tulokset eivät olleet tilastollisesti merkitseviä. Tulosten perusteella voidaan todeta, että VR oppimisvälineenä voidaan kokea positiivisemmin, kun sitä käytetään johdantona uuteen aiheeseen. Yhteistoiminnallista oppimista tavoiteltaessa tulisi kiinnittää huomiota positiivisen keskinäisen riippuvuuden ja vuorovaikutteisen viestinnän tukemiseen oppitunnilla, kun käytetään virtuaalista todellisuutta.

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oppiminen, virtuaalitodellisuus, yhteistoiminnallinen oppiminen, yhteenkuuluvuuden tunne

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1 Introduction

Extended reality (XR) technologies, i. e. technologies that include virtual reality (VR) and augmented reality (AR), have gained a wide interest in technology-enhanced learning research due to the potential assigned to new types of teaching and learning, as well as for being efficient and motivating for learners (Brown et al., 2020; Checa & Bustillo, 2020; Jensen & Konradsen, 2018). VR and AR have existed already for decades, and virtual reality applications for higher education purposes have been developed since the 1990s (Youngblut, 1998). The technology was previously deemed too expensive to consider for use in the classroom, but nowadays VR and AR are more accessible as the equipment is cheaper, and some applications can even be accessed from a personal smartphone (Brown et al., 2020; Radianti, Majchrzak, Fromm & Wohlgenannt, 2020). There has also been significant increase in the quality of the equipment and in terms of user experience (Jensen & Konradsen, 2018).

The research on the use of VR in education has been more focused on usability of the applications rather than the learning outcomes (Radianti et al., 2020). Most educational VR simulations are developed for self-learners and do not fit well for classroom use (Jensen & Konradsen, 2018). To benefit from VR technology in classroom, the application and lesson design should follow a pedagogically meaningful, thought-through plan or model (Mantovani, 2001).

In this study, experiences of cooperative learning and relatedness are examined in a traditional (hands-on) learning environment and in one applying virtual reality learning tools. Learning together in a supportive environment has shown to improve learning of all students, including both the best and the less achieving students (Johnson, Johnson & Holubec, 1994a). Cooperative learning also benefits learning of many general work-life skills, such as communication, leadership, and teamwork skills (Ballantine & McCourt Larres, 2007; Johnson & Johnson, 1991), often referred to as soft skills. The sense of relatedness can increase motivation and academic outcomes (e.g., Beachboard, Beachboard, Li & Adkison, 2011). Therefore, cooperative learning and relatedness could enhance learning with VR tools. Fairly little research has been performed on cooperative learning and relatedness experiences with VR tools, and this study will provide new insights on the topic, particularly the dimensions of experienced relatedness and its role in the learning setting.

Due to financial and other restraints, many schools often only purchase one or two pairs of VR headsets and controls to try out the new technology and its possibilities for teaching. These schools would benefit from a cooperative learning design that would make the most of the few pairs of VR headsets. Although only one user at a time is immersed in the VR environment, it is possible that others view the VR environment and their classmate's actions on a large screen. However, it can be hard for the teacher to retain the attention and motivation of the non-immersed viewers (Meyer, Becker, Mueller, Jeworutzki, Draheim & von Luck, 2021). With supportive technology and task design, the collaboration and communication between the one wearing the headset and the non-immersed viewers can be enhanced, which can then increase enjoyment, presence and social interaction of the learners (Gugenheimer, Stemasov, Frommel & Rukzio, 2017; Thoravi Kumaravel, Nguyen, DiVerdi & Hartmann, 2020). This type of situation can be referred to as asymmetric collaboration (Thomsen, Nilsson, Nordahl & Lohmann, 2019). There is relatively little research on shared use of VR devices (Liu, Wang, Lei, Wang & Ren, 2020).

The aim of this study is to examine students' experiences on how cooperative learning elements and peer relatedness are supported in different learning settings. In this study, a learning setting refers to a lesson design or a modality, where the used learning tools differ from another setting. The two learning tools in this study include a physical machine and a virtual machine accessed with virtual reality devices. Students' experiences from a regular workshop lesson with a real forestry machine are then compared to the experiences in a lesson with a virtual machine available.

First in the theoretical framework, the background of virtual reality and its use and research in education are described. Then the section 3 will look more into the elements of cooperative learning and research of cooperative and collaborative learning with virtual learning tools. Self-determination theory and how relatedness is related to cooperative learning are also briefly described. Then in section 4 the research task and research questions are described. Section 5 will describe the procedure and methods used in this study and section 6 will present the results of the study. The thesis ends in discussion at section 7, followed by references and appendices.

2 Virtual reality as a tool for learning

History of virtual reality

Jaron Lanier was the one to coin the term *virtual reality*, describing it as a technology that uses computerised clothing to create alternative worlds for a person's senses (Kelly with Heilbrun & Stacks, 1989). The term virtual reality was first introduced in 1987 (Lowood, n.d.), but the phenomenon was recognised previously under different terminology, such as 'responsive environment' (Krueger, 1977) and 'artificial reality' (Krueger, 1993). The first virtual reality simulator was already seen in 1960s, when Morton Heilig created Sensorama, a sensory system equipped with a variety of sensory stimuli, such as sound, wind, smell and vibration (Craig, Sherman & Will, 2009). Sensorama created a sense of immersion but did not include another essential element typical of VR – interaction (Craig et al., 2009; Mazuryk & Gervautz, 1999).

Krueger (1977) described responsive environments as a system where a computer interprets user's actions and responds to them by using visual and auditory feedback. Krueger later created an artificial reality system called VIDEOPLACE, which aimed to be an environment where the user could move freely and the computer would track and react to the user's movements (Krueger, Gionfriddo & Hinrichsen, 1985; Krueger, 1993). Krueger's work on artificial reality and VIDEOPLACE has inspired many that later worked on developing VR, and the multiple terms such as virtual reality, virtual environment, virtual worlds, and artificial reality can be identified to the same phenomenon (Gigante, 1993).

Features of virtual reality

Gigante (1993, p. 3) defined virtual reality (henceforth, VR) as "*The illusion of participation in a synthetic environment rather than external observation of such environment. VR relies on three-dimensional (3D), stereoscopic, head-tracked displays, hand/body tracking and binaural sound. VR is an immersive, multisensory experience*." According to Burdea and Coiffet (2003), the three most important features are interaction, immersion and imagination. Imagination is seen important as the development of VR applications requires imagination and creativity to solve problems, and the user of the VR application needs to be able to imagine the non-existent things that they perceive (Burdea & Coiffet, 2003).

Another important part of describing VR from the human experience perspective is *presence*, which refers to a feeling of being in an environment (Steuer, 1992). Presence is created by engaging one’s senses, capturing one’s attention, and supporting the feeling of one’s involvement in the environment (Witmer, Jerome & Signer, 2005). In a physical environment, presence is unmediated (Steuer, 1992). *Telepresence* refers to an experience of presence in a mediated environment, that is accessed through a communication medium (Steuer, 1992).

Immersion in VR environments refers to a type of spatial immersion, where the used technology creates a feeling of being physically present in a virtual world (Freina & Ott, 2015). Immersion is also increased by experiences of direct interaction and continuous stimuli from the environment (Witmer et al., 2005). Dede (2009) stated that there are four immersion designs that create powerful immersion for enhancing learning: actional immersion, symbolic/narrative immersion, sensory immersion, and social immersion. *Actional immersion* involves the user experiencing a novel action that can be impossible in the real world (Dede, 2009; Liu, Dede, Huang & Richards, 2017). *Symbolic/narrative immersion* makes the user emotionally associated to the content and experience, such as escaping a terrifying monster (Liu et al., 2017). *Sensory immersion* is created by supporting sensory feedback, that creates a feeling of being in the virtual environment and being able to interact with it (Dede, 2009). Sensory immersion is often used for procedural learning applications (Liu et al., 2017), and can be achieved with fully immersive VR devices, such as head-mounted displays (HMDs) or virtual reality rooms (Dede, 2009). In *social immersion*, social connections with participants sharing the same virtual space increase the feeling of immersion (Liu et al., 2017). These immersion designs can separately or combined create strong immersive feelings to the learner (Dede, 2009; Liu et al., 2017).

Interactivity refers to a situation, where the user can modify and form the content of an environment in real time (Steuer, 1992). Virtual reality uses interactive devices, such as goggles, headsets, and gloves to enable real-time interaction with the virtual environment and enhance the immersion of the user (Lowood, n.d.). Different types of virtual reality can be grouped by their level of immersion: Desktop VR, Fish Tank VR, and Immersive Systems (Mazuryk & Gervautz, 1999). Desktop VR only uses a regular computer monitor to visualise the virtual world, where tasks can be of then completed with a mouse and a keyboard (Mazuryk & Gervautz, 1999; Wang, Wu, Wang, Chi & Wang, 2018). This technology is a cheaper option, as it does not require any equipment other than a regular computer (Wang et al., 2018). Fish Tank VR is an improved version from Desktop VR that creates a more immersive feeling with head movement tracking (Mazuryk & Gervautz, 1999). Fully immersive systems are the most enhanced versions of virtual reality, which use HMDs or Cave Automatic Virtual Environments (CAVE) systems to create a motion-responsive environment (Freina & Ott, 2015; Mazuryk & Gervautz, 1999).

Virtual reality in education

The potential of VR technologies and its features in education have been widely recognised, and experiments and research around them have increased rapidly (Brown et al., 2020). VR applications in higher education are most often used to teach and learn procedural-practical knowledge, declarative knowledge, analytical and problem-solving skills and communication, collaboration and soft skills (Radianti et al., 2020). Häfner (2020) developed seven main categories of benefits and possibilities of immersive learning tools based on a literature review, expert interviews and user reports: enhancing learning outcomes, increasing motivation and concentration, advancing soft skills, safety and health protection, saving time and costs, adapting to individual needs, and facilitating teaching.

The research on VR-based education technologies aims to find ways to improve learning results with the technology, however, there have been mixed results on how VR applications affect learning outcomes. Immersive VR seems to be more effective than less immersive applications. Immersive VR has been shown to enhance higher conceptual understanding (Lui, McEwen & Mullally, 2020). Kwon (2019) compared two immersive learning situations, where a HMD was used to access a virtual world and it was controlled either with a PlayStation 4 gamepad (VR) or with movement-tracking and two hand-controllers (AVR, authentic virtual reality). No difference was found in learning tasks that measured remembering, understanding, and applying questions, but the AVR had better results in analysing, evaluating and creating questions (Kwon, 2019). A fully immersive VR with an HMD was also found more effective than desktop VR in medical education (Gutiérrez et al., 2007). In Jensen and Konradsen's (2018) review, using a HMD was found useful for learning in three situations: cognitive skill acquisition related to remembering and understanding spatial and visual knowledge, psychomotor skills related to head movement (for example observational skills), and affective skills related to controlling emotional responses.

However, sometimes less immersive applications have led to better learning outcomes. Moreno and Mayer (2004) compared a highly immersive VR application (HMD) to a low immersion VR application (desktop VR) and found that the low-immersion groups scored better on the retention test and transfer test than the high-immersion groups. One aspect that might reduce learning in immersive VR applications is the *cognitive load* that distracts the learner's focus from the actual content (Moreno & Mayer, 2004). There are three types of cognitive load: *intrinsic load* (related to the complexity of the learning task), *extraneous load* (unnecessary processes that are present in the learning situation) and *germane load* (mental efforts that contribute to the constructions of schemas) (Sweller, van Merriënboer & Paas, 1998). Frederiksen and colleagues (2020) found that an immersive VR simulation training produced higher cognitive load in surgical skills training than less-immersive VR simulation, and that the less-immersive group also performed better than the immersive group. The immersive groups' cognitive load was increased more than that of the less-immersive groups when light and severe stressors were added to the training situations (Frederiksen et al., 2020). On the other hand, annotations in VR learning environments can foster germane cognitive load and produce higher recall in the students (Albus, Vogt & Seufert, 2021).

In addition to potentially improving learning outcomes, immersive VR has other benefits for learning. Immersive VR can be used as an experimental learning tool and it has a potential for increasing participation, interaction, engagement and motivation for learning (Mantovani, 2001; Wang et al., 2018). Interactivity of immersive VR environments support active participation and self-directed learning (Pantelidis, 2010). VR can give more freedom in interactivity and allow students to be creative (Villagrasa, Fonseca & Durán, 2014). Also, gamification elements can be added to VR learning activities to increase motivation and engagement (Checa & Bustillo, 2020; Villagrasa et al., 2014).

Studies have shown that an immersive virtual environment does not suit all learners, as it can cause physical discomfort and "cybersickness" which will affect learning outcomes and the learning experience (Jensen & Konradsen, 2018). Simulator sickness has been found to hinder the experiences of presence, flow and engagement, which can then decrease motivation and learning (Maraj, Badillo-Urquiola, Martinez, Stevens & Maxwell, 2017). Though, Nichols, Haldane and Wilson (2000) suggest that the association of sickness and presence is mediated by the physical interface rather than the VR environment or the interactions made there.

The phenomenon can be compared to motion sickness in vehicles, and often happens in situations where the user experiences movement in the virtual world but is not physically moving to match what they see (Rogers, El-Mounaryi, Wasfy & Satterwhite, 2017). Symptoms can include problems in vision (eyestrain, blurriness), headache, nausea, and disorientation (dizziness, vertigo) (Davis, Nesbitt & Nalivaiko, 2014). Less immersive desktop VR applications have been found to cause less cybersickness than immersive VR applications (Dede, Salzman, Loftin & Ash, 1997). Women have been found to experience more motion sickness than men when using virtual technologies (Munafo, Diedrick & Stoffregen, 2017).

Even though there are some difficulties with the implementation of VR applications, there are still other benefits that are pursued with the development of VR. It has been found that VR simulation training can produce the same learning outcomes than traditional training (Kaplan et al., 2021). Therefore, VR applications are developed as alternatives for dangerous and/or expensive, but necessary trainings, such as in medical, aviation, military and emergency training (Ausburn & Ausburn, 2004). The VR simulations allow the students to get more experience and skills training as an addition or partial replacement of their practical training. A VR environment can also enable learning about situations that cannot be otherwise brought to classrooms, for example by creating a virtual field trip (Mantovani, 2001; Petersen, Klingenberg, Mayer & Makransky, 2020). VR allows the learner to take different perspectives and discover for example a model of a molecule from different angles or go inside it (Pantelidis, 2010).

The possibility of having new kinds of experiences for learning does not only include hard skills training. VR can be used for training soft skills, such as communication, leadership, teamwork and problem-solving skills (Häfner, 2020; Hickman & Akdere, 2017). For example, Zhao and Ma (2020) developed a virtual agent to train elevator pitches, that gave feedback on the speech immediately and after the pitch. Their considerations for best results were that the feedback should be timed correctly, be reasonable and match the users' mental model, and challenge the user at the right skills level (Zhao & Ma, 2020). A VR application developed for public speaking enhanced the participants' gesture control and speech rate compared to practicing only with a real audience (Notaro, Capraro, Pesavento, Milani & Busà, 2021). VR can also give new types of experiences and change the typical point of view in training. For example, Zhou, Fujimoto, Kanbara and Kato (2021) developed a VR-based public speaking training system that allowed the users to reflect their public speaking performance by watching a virtual avatar perform their presentation in VR, rather than a video recording of themselves. This was seen beneficial for individuals with low self-confidence and negative self-bias, as they could focus more on the content rather than personal appearance (Zhou et al., 2021).

VR environments and learning applications are very customisable and they can be adapted to individual learner's needs (Mantovani, 2001). There is also interest in developing applications to support learners with special needs, such as learners with learning disabilities, autism or physical disabilities (Jeffs, 2010; Youngblut, 1998). VR applications can for example provide modelling, different instructional designs, realistic training environments, sensory experiences, stimulus control and mobility training (Powers, & Melissa, 1994).

The customisability of VR is a benefit for teachers, too. VR allows the teachers to use different pedagogical approaches, customise the content for specific needs or goals of the class, and give automated feedback for students based on their actions (Häfner, 2020). Bower, DeWitt and Lai (2020) explored preservice teachers' perceptions and intentions of using immersive VR in teaching. Preservice teachers perceived that VR could improve their performance as teachers (with providing new experiences, immersion, interaction and more concentration to students), potentially save preparation time and make learning enjoyable for students (Bower et al., 2020). Preservice teachers' intentions of using VR in teaching were reduced by concerns related to external factors (such as the schools' resources and support from colleagues), internal barriers (such as negative attitudes towards the technology, lack of experience with the technology) and design factors (such as creating pedagogically meaningful tasks within the applications) (Bower et al., 2020).

The research and use of VR is focused more on individual experiences and performance rather than collaborative use. In the next chapter, the benefits of cooperation and peer relatedness for learning are discussed, following up with an overview of research of collective experiences with VR learning tools.

3 Cooperation and relatedness in learning

Cooperative learning theory

Cooperation refers to working together in a group towards a shared goal or a task, and cooperative learning can be described as institutionalised use of small groups of students that work together to enhance their own and their group's learning and success (Johnson et al., 1994a). The concept of working together in groups in educational contexts has been referred by many terms in research, cooperative learning and collaborative learning being the most common (Barkley, Cross & Major, 2005). The terms have similar definitions, and sometimes are used as synonymic expressions. There are different interpretations on the differences of these two phenomena: some say that cooperative learning is a subcategory of collaborative learning (Cuseo, 1992). Some differences that are described for the phenomena are that cooperative learning is more structured and teacher-centered, and includes stricter division of work between group members, while in collaborative learning group members are working more together, and less dividing their work (Dillenbourg, 1999; Panitz, 1999).

After a dominant period of individualistic learning, cooperative learning became widely accepted in the 1980s (Johnson & Johnson, 2009). At that time, social scientists began to shed light on how important peer relationships were to children's development and learning (Ladd, 1999; Johnson, 1981). A literature review of 122 studies that was published in 1981 highlighted that cooperative learning was more effective in promoting higher achievement than interpersonal competition and individualistic efforts (Johnson, Maruyama, Johnson, Nelson, & Skon, 1981). The main figures behind the recognition of the importance of cooperation were Karl Smith, and David and Roger Johnson, and they brought the idea first in K-12 education and later in higher education (Barkley et al., 2005). Compared to competitive and individualistic learning, Johnson and colleagues (1994a) recognised three main benefits of cooperation in students: greater efforts to achieve, more positive relationships among students and greater psychological health.

Cooperative learning theory has a foundation in social interdependence theory (Johnson & Johnson, 2009). The beginning of theorising social interdependence can be traced back to the early 1900s, when one of the founders of Gestalt School of Psychology, Kurt Koffka, proposed that groups were dynamic wholes, and interdependence between group members can vary (Johnson & Johnson, 2002; 2005; Koffka 1935/2005). Kurt Lewin later refined the theory by stating that interdependence among the members of a group is the essence of a group, where a change in the state of one of its members changes the state in other group members (Johnson & Johnson, 2002; 2005; Lewin, 1935). An intrinsic state of tension between group members motivates their work towards shared goals (Johnson & Johnson, 2002; 2005; Lewin, 1935). Morton Deutsch extended Lewin's theory and differentiated between two types of interdependence, launching the theory of cooperation and competition (Deutsch, 1949; Johnson & Johnson, 2005). Positive interdependence exists when one's actions support reaching joint goals, and negative interdependence exists when one's actions hinder others' success (Johnson & Johnson, 2005; 2009). Social independence, in turn, refers to a situation where one's actions do not affect others' success (Johnson & Johnson, 2002). Positive interdependence is one of the key elements of cooperative learning (Johnson et al., 1994a). Negative interdependence can be associated with competitive learning structures and social independence to individual learning structures (Johnson & Johnson, 2002).

Cooperative learning and relatedness

In addition to promoting higher achievement, cooperative goal structures in classroom have been found to promote more positive peer relationships in early adolescents compared to competitive and individualistic goal structures (Roseth, Johnson & Johnson, 2008). Peer relationships have been shown to be important for intrinsic motivation, which is often studied from self-determination theory's perspective. Self-determination theory considers people to have three psychological needs that are essential for intrinsic motivation: autonomy, competence, and relatedness (Deci & Ryan, 2000). *Autonomy* refers to a need of self-regulating one's actions and experiences (Ryan & Deci, 2017). When autonomy applies, the person can work within their own interests and values (Ryan & Deci, 2017). *Competence* is a person's need for feeling of being able to do the things that they want or need to do and doing them effectively (Ryan & Deci, 2017). *Relatedness* refers to a need for being socially connected (Ryan & Deci, 2000). Feeling of relatedness exist in situations where one feels being cared for by others, and it also includes a sense of belonging among others (Ryan & Deci, 2017). The sense of belongingness needs lasting, positive, and significant interpersonal relationships, and frequent interaction with the same people give more satisfaction than a constantly changing social circle (Baumeister & Leary, 1995). In addition to receiving care from others, feeling of supporting others and contributing to other's wellbeing is also an important part of relatedness (Ryan & Powelson, 1991). Cook and Artino Jr (2016) concluded that relatedness is enhanced with respect, caring, security and inclusive environment, and weakened by competition, criticism, cliques and traditions. Supporting relatedness has proven to be beneficial to motivation and learning outcomes (Beachboard et al., 2011).

Individual-level motivation is often examined from self-determination theory's perspective, but its elements could be beneficial to a group's motivation. Thomas, Amiot, Louis and Goddard (2017) integrated self-determination theory with the social identity approach to study a phenomenon they called *collective self-determination*. They found that collective self-determination predicts support for intergroup helping, group pride and well-being more than individual-level self-determined motivation (Thomas et al., 2017). Therefore, supporting relatedness can be beneficial in promoting cooperative learning in classroom.

Cooperative learning and the three psychological needs have been found to be positively connected. For instance, Hänze and Berger (2007) found that students learning using the jigsaw cooperative learning method (where students first learn about specific subject in groups and then separate to teach other groups what they have learned) rated their autonomy, competence and social relatedness higher than students learning with the traditional lecture method. Higher rated cooperative learning experiences have been found to be positively connected to autonomy, competence and relatedness in physical education (Chu, Zhang & Cheung, 2019).

Recent studies have shown that cooperative learning can support peer relatedness in various contexts. Cooperative learning promotes social relatedness better than competitive learning (Dindar, Ren & Järvenoja, 2021). Cooperative learning interventions supported sense of belonging and relatedness in multicultural and multilingual classrooms (Buchs & Maradan, 2021). Van Ryzin and Roseth (2021) also found that cooperative learning enhances peer relatedness in classroom, but it also having positive effects on reducing stress and emotional problems and enhancing academic engagement as direct and indirect effects. Emphasis on cooperative learning and peer relatedness positively predicted social cohesion among athletes (Weiss, Moehnke & Kipp, 2021). Cooperative learning through coach and teammate relatedness also predicted personal and social responsibility in youth soccer (Kipp & Bolter, 2020). Regarding these results, both cooperative learning and relatedness are recommended to be structured in a lesson design.

The five elements of cooperative learning

Cooperative learning has five key elements that are recommended to be structured in a lesson design: positive interdependence, individual accountability and personal responsibility, promotive interaction, appropriate use of social skills, and group processing (Johnson et al., 1994a; Johnson & Johnson, 2009). All these five elements should be incorporated in the learning activity for the groups to work truly cooperatively (Johnson & Johnson, 1991).

The most important element in cooperative learning is *positive interdependence* (Johnson et al., 1994a). Positive interdependence means that students' successes are linked to each other: they all reach the same goal or grade (Johnson & Johnson, 1991). This means that all work should be seen beneficial for the whole group and it should encourage for example peer support and sharing resources during the cooperative work (Johnson et al., 1994a). The students should feel responsible for not only their own learning but also the learning in their group (Barkley et al., 2005).

Positive interdependence can be achieved in many ways, that can be divided into three categories: outcome interdependence, means interdependence and boundary interdependence (Johnson & Johnson, 2009). Outcome interdependence includes positive goal and positive reward interdependence (Johnson & Johnson, 2009). In *positive goal interdependence*, the group is given a mutual group goal so that the learning goal is only achieved if all members achieve it, for example learning a specific material (Johnson, Johnson & Holubec, 1994b). Every cooperative lesson should include some positive goal interdependence, so that it eventually becomes a natural part of classroom learning (Johnson et al., 1994a). At the beginning of practising cooperative learning, mutual goal might not ensure cooperation in the group, so other cooperative learning structures can be added to the lesson design (Johnson et al., 1994a). Joint reward can be added to structure *positive reward interdependence*, for example bonus points if all group members reach a certain grade in their exams (Johnson et al., 1994b).

Means interdependence is structured with resource, role and/or task interdependence (Johnson & Johnson, 2009). *Positive resource interdependence* includes divided resources, so that group members must combine the different resources or materials they have been given in order to complete their task (Johnson et al., 1994a). In *positive role interdependence*, each member of the group is given complementary roles that have different responsibilities in the common task (Johnson et al., 1994b). There are many different types of roles that can be used, and they can be divided by their functions:

forming the group (e.g. noise monitor, turn-taking monitor), helping the group function (e.g. recorder, encourager of participation), formulating what the student know (e.g. summariser, checker of understanding) or elaborating ideas and knowledge (e.g. criticiser of ideas, options generator) (Johnson et al., 1994a). *Positive task interdependence* is where completing a task is dependent on others' task completion, for example each member is responsible for one part of a larger project (Johnson & Johnson, 2009; Johnson et al., 1994b).

Boundary interdependence structures include *positive identity interdependence* (building group identity by a group name or a motto), *environmental interdependence* (groups are assigned their own areas to meet and work) and *outside enemy interdependence* (groups compete against each other, negative interdependence between groups) (Johnson & Johnson, 2009; Johnson et al., 1994a; 1994b). The different boundary interdependence methods are not independent from each other and can be used at the same time (Johnson & Johnson, 2009). Also, multiple positive interdependence types can be combined in a lesson plan, which will make cooperative learning stronger (Johnson et al., 1994a). Positive interdependence is the most important element of cooperative learning, and it can support structuring other cooperative learning elements in a lesson.

Positive interdependence supports *promotive interaction*, which is another key factor to cooperative learning (Johnson & Johnson, 2009). Promotive interaction indicates that the student group contributes to each other's learning by helping, encouraging, and sharing resources with other students (Johnson et al., 1994a). This should preferably be face-to-face (Johnson et al., 1994a), and happen in small groups of 2 to 6 people (Johnson & Johnson, 1991). Promotive interaction also helps students to revise what they know already, as they explain, discuss, solve problems and challenge each other's conclusions related to the studied content (Johnson et al., 1994a; 1994b). Positive interdependence is important for promotive interaction as it provides a context for meaningful student interaction between group members (Johnson et al., 1994b).

The third essential element of cooperative learning is *individual accountability*, which materialises when the performance of each student in a group is also individually assessed (Johnson & Johnson, 1991). The teacher should pay attention to how much each group member is participating and give feedback both to groups and individuals (Johnson et al., 1994b). This ensures that each member does their part on the group assignment and feels accountable for achieving the mutual goal (Johnson et al., 1994a).

The aim of individual accountability is that cooperation enhances each members' learning and success, not just the group performing better than each person individually (Johnson & Johnson, 1991). There are many structures that support individual accountability, such as small group size, individual tests, asking random students to explain the group's work orally, observing and recording everyone's participation, assigning a role of a participation checker in each group and having students teach their peers what they have learned (Johnson et al., 1994b). Individual feedback, compared to group feedback, has been found to create experiences of greater interdependence between group members (Archer-Kath, Johnson & Johnson, 1994).

Appropriate use of social skills is the fourth essential element of cooperative learning, and these skills are necessary for effective teamwork (Johnson et al., 1994b). To have group members working efficiently, the students must learn leadership skills, decision making, conflict management, communication skills, build trust in each other and be motivated to cooperate (Johnson et al., 1994a). It has been found that instruction, observation and feedback on cooperative skills resulted more positive interaction and peer relationships (Putnam, Rynders, Johnson & Johnson, 1989).

The fifth essential element in cooperative learning is *group processing*. In group processing group members reflect on how effective their working has been in regards on how they have reached their goals (Johnson et al., 1994a). The students should discuss together which actions have been helpful and which have not and decide what actions they will continue and what they will change (Johnson et al., 1994b). The purpose is to continuously improve the learning process and clarify how group effectiveness can be enhanced (Johnson et al., 1994a). It is recommended that some time is allocated for group processing at the end of each lesson (Johnson et al., 1994b). Implementing all five elements of cooperative learning in lessons regularly gives conditions for best outcomes (Johnson et al., 1994a).

Benefits of cooperative learning

Cooperative learning has been proven beneficial for learning and outperforming individualistic and competitive learning structures (Johnson et al., 1981). It can improve academic achievement (Felder, 1995; Roseth et al., 2008), motivation (Johnson, Johnson, Roseth & Shin, 2014) and student relatedness (Van Ryzin & Roseth, 2021). Shimazoe and Aldrich (2010) concluded that cooperative learning benefits students by promoting deep learning and personal growth, helping to achieve better results, teaching social skills, civic values, and higher order thinking skills, and developing positive attitudes towards autonomous learning. The benefits for teachers include for example that it gives more opportunities to reflect students' learning and decreases grading load (Shimazoe & Aldrich, 2010). However, Nokes-Malach, Richey and Gadgil (2015) noted in their literature review that sometimes students learning together have had either no difference in results or even weaker results than learners individually, so benefitting from cooperation should not be taken for granted. When considering the potential benefits of cooperative learning and VR for learning, it is interesting to study how both of them together could enhance learning experiences and results. Generally, research on VR and AR technologies usually does not take the perspective of learning theories, instead, it has focused more on enhancing usability or diminishing technical issues (Radianti et al. 2020; Puggioni, Frontoni, Paolanti, & Pierdicca, 2021). Next, I will discuss research into cooperative learning applying virtual tools.

Cooperative learning with virtual learning tools

3D virtual learning environments can be used to facilitate collaborative learning, and 3D environments have been proven to support cooperative learning better than a 2D world (Dalgarno & Lee, 2010). However, only few VR applications support multiple users in the same environment. As there is little research from the perspective of group learning on the use of VR technologies, I will present an overview of how both cooperative and collaborative learning are studied in the context of VR and AR learning.

The research on cooperative learning, utilising VR's and AR's potential, has yielded contradictory results. Puggioni and colleagues (2021) developed an AR and VR application ScoolAR and found that the student groups using VR were able to work cooperatively and take different roles and responsibilities with the tasks and had greater percent of correct answers in the final test. Elford, Lancaster and Jones (2021) developed an AR and an iVR (immersive virtual reality) educational escape room and discovered that the escape room activity helped the students to discover the material and their findings as a team, and the best performing group also had the most interaction between teammates. AR systems are also seen as potential tools for supporting collaboration by increasing social interaction, communication and engagement students (Matcha & Rambli, 2012). In López-Faican's and Jaen's (2020) study, collaborative use of a mobile AR game was found to have a greater impact on children's emotional affection, social interaction and interest. They were able to design multiple aspects that supported cooperative learning in the game, such as a common goal, positive interdependence, individual accountability and joint rewards (López-Faican & Jaen, 2020). Also, a collaborative mobile AR system produced better test results than a 2D simulation system (Lin, Duh, Li, Wang & Tsai, 2013). It seems that VR and AR technologies can support cooperative learning and enhance learning outcomes.

In these cases, cooperation and collaboration supported the learning objectives in the lessons with virtual tools, but in some cases collaborating has not led to better results. Chen (2008) discovered that a student group learning alone with an AR tool performed better than a collaborating AR group, though students evaluated that collaboration was helpful in their learning process. When learning with VR simulation games, a literature review of Merchant, Goetz, Cifuentes, Keeney-Kennicutt and Davis (2014) found that students that learned individually got better results than those who collaborated. In some cases, no differences between groups of different learning styles have been found, for example Wagner, Schmalstieg and Billinghurst (2006) developed a collaborative AR game Virtuoso for studying art history and found no differences in educational outcomes with the Virtuoso, PC and paper conditions. However, the participants reported that the small screens of Virtuoso made collaboration more difficult (Wagner et al., 2006).

Sometimes, due to a limited amount of devices or limitations in applications, students need to share the VR devices, which can change the way the students can collaborate. Collaboration in learning settings where one student is immersed in the VR by an HMD and one or more students are not immersed is referred as asymmetric collaboration (Thomsen et al., 2019). Thomsen and colleagues (2019) recognised three levels of asymmetry, where the abilities of the non-immersed participant differ: in low asymmetry the participant can directly interact with the environment, medium asymmetry allows indirect interaction and high asymmetry does not allow interaction. Even with asymmetric collaboration, increase in enjoyment, presence and social interaction can be achieved with supportive system and lesson designs (Gugenheimer et al., 2017; Thoravi Kumaravel et al., 2020). Effective use of shared VR devices during learning activities is a topic that is yet not studied much (Liu et al., 2020). Next, I will move to the topic of experiences of relatedness when using virtual learning tools.

Relatedness and virtual learning tools

The experiences of relatedness when learning with a VR tool have not been studied much, and the influence of the level of immersion is not discussed. Chao, Jong and Luk (2021) studied an online VR language learning course and found that the VR tool increased the amount of student-student and teacher-student interactions, in addition to enhanced experiences of autonomy and competence. Huang, Backman, Backman, McGuire and Moore (2019) found that experienced relatedness in a 3D virtual world was positively linked to intrinsic motivation, behavioral intentions, emotional involvement, and flow. Barreda-Ángeles & Hartmann (2022) found that stronger spatial and social presence were associated to increased feelings relatedness when using social VR applications. Only few studies have examined the influence of VR technologies to relatedness in learning, and this study will contribute to this research topic.

Cooperative learning can be beneficial for learning in many ways (Shimazoe & Aldrich, 2010) and relatedness has also an impact on individual motivation and learning outcomes (Beachboard et al., 2011), and some of these benefits have been found also in interventions with VR tools (Huang et al., 2019; Elford et al., 2021). Cooperative learning has been found to support peer relatedness (Van Ryzin & Roseth, 2021), so it is interesting to see how it can be supported in lessons that use VR learning tools. In the next chapter, the aims of the current study and the research questions are described.

4 Research task and research questions

This study compares students’ experiences of cooperative learning and relatedness of two student groups in two different learning settings. In this study, learning setting refers to a lesson design or a modality, where the tools used for learning are in central focus. The student groups participated in both learning settings, but the order of the lessons with different learning tools varied. The first learning setting is a situation where a group of students are learning in a traditional workshop environment with a physical forestry machine with digital devices to view instructions and manuals. In the second setting, one person at a time has access to a VR environment with a virtual forestry machine, while the other students follow the actions on a screen and give advice. In both cases, students follow a worksheet and work together with given exercises.

Virtual reality has the potential of providing multiple benefits for learning and teaching (e. g. Häfner, 2020). When incorporating cooperative learning and relatedness to the VR training, it can enhance learning results in VR. Cooperative learning and peer relatedness have been found positively connected (e. g. Roseth et al., 2008). This study is focused on collective experiences with VR learning tools, so experiences of cooperative learning and relatedness were chosen as the main themes.

The aim of this study is to map good practices and develop cooperative learning with one piece of a virtual reality headset. This study set out to understand student experiences in two different learning environments through the following research questions:

1. What kinds of cooperative learning experiences do the students report
    a. when studying with a virtual reality learning tool,
    b. when studying with a physical machine,
    c. when they compare their experiences with different tools?
2. What kinds of differences can be identified in the experienced relatedness in the two different learning settings?

To answer these questions, a mixed-methods approach was applied to understand and map the similarities and differences in experiences of cooperative learning and relatedness of two different student groups in two different learning settings. For the first research question, students were interviewed about their experiences in the two different lessons and their descriptions were analysed with theoretical thematic analysis. For the second research question, results of post-training questionnaires of each lesson were analysed from tool/technology relatedness and training relatedness perspective with Wilcoxon Signed Ranks test.

5 Methods

5.1 Research project and research approach

This study was conducted in the joint research project of the Mixed Reality Hub and the Caledonia Hub research groups at the University of Helsinki. The joint research project aims investigate learning in virtual reality environments and develop approaches to assessing and evaluating learning in these non-traditional learning contexts. The development work takes place in two different learning contexts provided by two Finnish companies in forest and mining industry. The research objectives include: 1. identifying the most efficient virtual reality learning environment (VRLE) design in terms of learning antecedents and outcomes 2. improving design knowledge about holistic education systems and learning paths combining VRLEs and conventional ones 3. validating a self-determination scale developed for VRLEs. The research design of the project consists of three phases which are described in Figure 1.

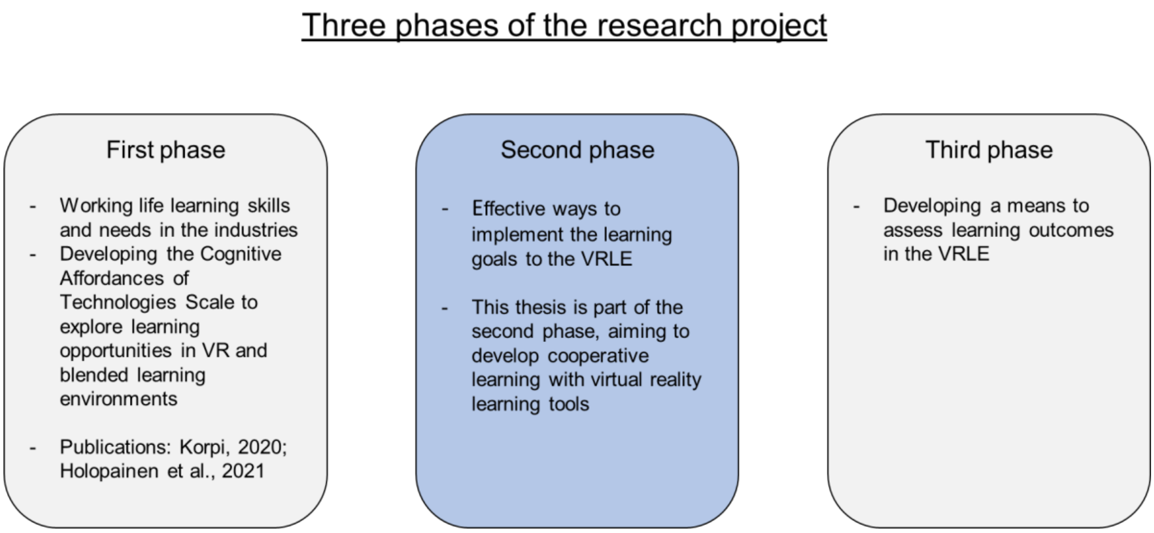

Figure 1. Three phases of the research project

This study is a mixed methods study (Greene, Caracelli & Graham, 1989). This approach was chosen to gain more understanding of the phenomenon, explain more of the quantitative interview data, and to give more reliability to the quantitative analysis done for a small sample of questionnaire data of participating students. This type of mixed methods study is called a complementary design, where overlapping phenomena are studied from different perspectives and two research methods are applied simultaneously (Greene et al., 1989). In this study, qualitative and quantitative data were collected at the same data collection days, and all data were analysed only after the whole data collection, so primary results did not influence either of the data collection methods.

Figure 2 below describes the research design on how relatedness and five elements of cooperative learning are supported in two lesson designs, workshop lesson and a lesson with a VR learning tool. The five elements of cooperative learning examined are: positive interdependence, individual accountability, promotive interaction, appropriate use of social skills and group processing.

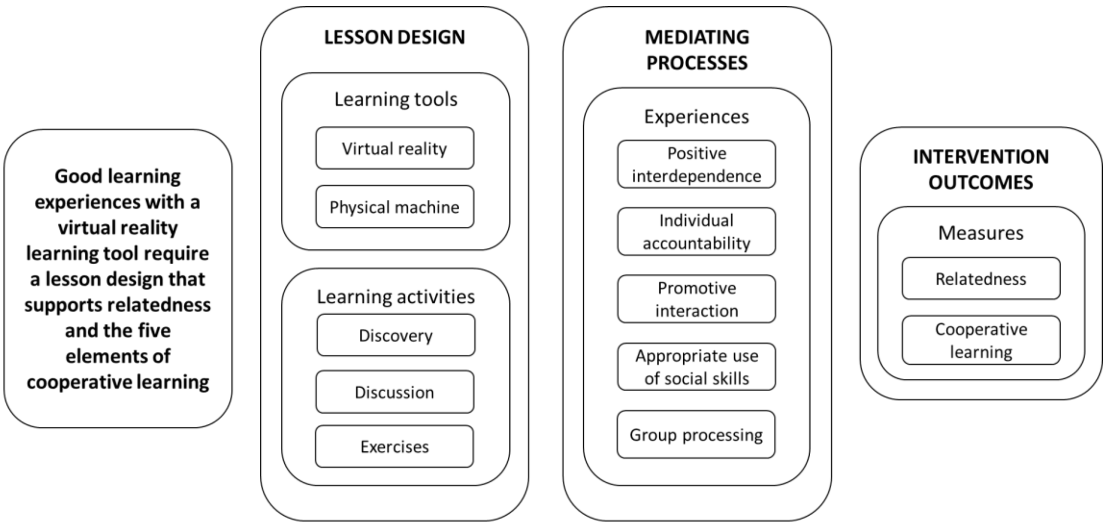

Figure 2. Design of the intervention and the study

5.2 Participants

A total of 35 forest-industry students participated in the study. They represented two Finnish educational institutions, one vocational school (*n* = 21) and one university of applied sciences (UAS) (*n* = 14). The vocational school students were mostly in the first or second year of their studies, and the students in the university of applied sciences were in their fourth or fifth year. All the participating students were identified as male based on their first names. The students took part in the research in a mandatory course in their study program, but the students gave a separate approval to use their questionnaire data and interviews for research purposes.

5.3 Two learning settings

Objectives of the lessons and task procedure

The learning objectives for both VR and workshop lessons were getting to know the main components of the harvester and the boom, understanding the procedure and being able to perform maintenance for the essential parts. This study could give insight for how achieving these objectives could be enhanced by supporting cooperative learning and relatedness in the two lessons.

The students in the vocational school were assigned to fill out paper worksheets as a lesson activity. The aim of the exercises was to support the learning process. These worksheets included the following questions (same questions for both VR and workshop lessons):

1. General information of the harvester head
    a. Model
    b. Where in the harvester collection is the harvester head located?
2. Technical information:
    a. Weight
    b. Feeding unit (feeding force, feeding speed, feeding system)
    c. Delimbing unit (number of knives, maximum opening of knives)
    d. Saw unit (saw bar length, cutting diameter, chain type)
3. Main phases of logging operation
4. Lubrication objects – pictures
5. Main phases of lubrication and their purpose
6. Main components of the colour marking equipment
7. The operations of the colour marking equipment
8. Maintenance of the colour marking equipment

Virtual reality lesson

For the virtual reality lesson, a virtual simulation of the physical machine was created in the VR environment. Participants in virtual reality lesson used one set of head-mounted display to enter the virtual world and two controllers in their hands to interact with the world and objects. The device used was HTC Vive with two hand controllers. The immersive VRLE was developed by an external company. The environment supported moving around with either walking or teleporting and interaction with the harvester. Other students in the group followed the person’s actions in the VR through a video display of the person’s view. They could communicate with each other and give advice to each other. The students took turns in trying the virtual learning environment and the guided tasks. The level of immersion varied between students, the one using the HMD at the time had a fully immersive experience and others that watched the screen did not have an immersive experience. One student chose not to use the headset and only participated by following the classmates’ actions on screen. A picture from one of the VR lessons is presented in Figure 3, and a map of the learning setting in the VR lesson can be viewed in Figure 4.

The objective for the lesson was to learn about different parts of a forestry harvester and lubrication of its parts. The students were given paper instructions of the lesson plan, tasks for the virtual environment and exercises about the machine and its functions. The VRLE had also audio and visual guidance that told the student what to do next. If needed, the teacher would help the group with the virtual environment or the tasks. The first activity in the training was to disassemble the harvester in the right order and get to know the different parts and their functions. Next, they learned about the lubrication and related maintenance operations. The third part included the colour mark up, related components and maintenance. The students in the vocational school also filled in a worksheet explaining the processes in the lesson (see *Objectives of the lessons and task procedure*).

Figure 3. Picture from the VR lesson (Photo: Jani Holopainen / research material of the joint research group)

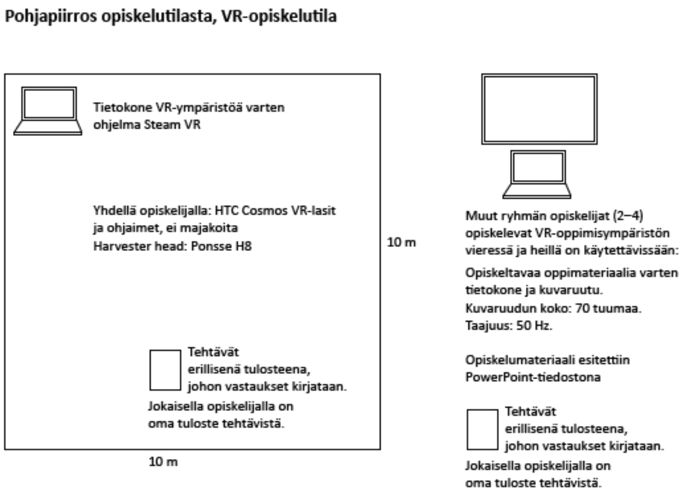

Figure 4. Presentation of the VR lesson (Schematic: Leena Närhi / research material of the joint research group)

Workshop lesson

The workshop lesson included mostly the same content as the virtual training, but it was taught in a workshop classroom setting with a teacher and a physical device. The first task was to learn about specific parts of the harvester and their functions from the manual. With the physical device, it was not possible to disassemble any parts. The following tasks were the same as in VR, getting to know the lubrication and colour mark-up processes and devices. The students in the vocational school also filled in a worksheet explaining the processes in the lesson (see *Objectives of the lessons and task procedure*). A picture from one of the workshop lessons can be seen in Figure 5, and a map of the learning setting in workshop lesson is presented in Figure 6.

Figure 5. Picture from the workshop lesson (Photo: Jani Holopainen / research material of the joint research group)

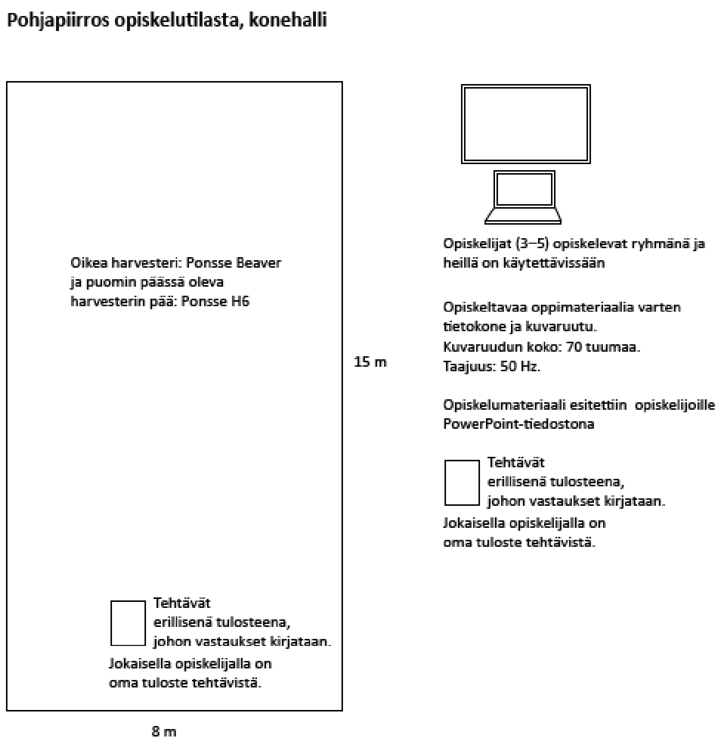

Figure 6. Presentation of the workshop lesson (Schematic: Leena Närhi / research material of the joint research group)

5.4 Instruments and structure of the questionnaires

5.4.1 Development and testing of questionnaires

Three components of the self-determination theory, autonomy, competence and relatedness, were measured with regards of the learning tools (VR or physical device) as well as the lesson as a whole. The items in the autonomy, competence and relatedness scale were developed from Cook and Artino Jr's work (2016). Autonomy was measured with a 10-item scale, competence with four items and relatedness with nine items. Questions were translated into Finnish and adapted to fit the context. Used scales and examples of questions are described in Appendix 3.

The pre- and post-training questionnaires were tested with people with different backgrounds to make sure that the items were understandable for the students and therefore more reliable. The researchers collected the comments and made small changes to the final versions of the questionnaires.

5.4.2 The structure of the questionnaires

At the beginning of the questionnaires the students gave their approval for using their answers as research data. The pre-training questionnaire then asked students' background information: lesson type (VR/workshop), name (removed for analysis), school, study year, previous experience with VR and work experience. After the background questions, the questionnaire included a motivation scale, rated on a seven-point Likert scale on a range from 1 (completely disagree) to 7 (completely agree). The pre-training questionnaire ended with two open questions testing their knowledge level before the lesson.

The post-training questionnaire included a name field for combining the answers from the same student (name removed for analysis). Then the students filled out the motivation scale again, followed by a choice for the lesson they attended (VR or workshop). Then according to their choice, they filled out scales related to learning experiences: technology/tool autonomy, technology/tool competence, technology/tool relatedness, training autonomy, training competence, training relatedness, presence, engagement, flow and teacher efficacy. All scales were rated on a seven-point Likert scale on a range from 1 (completely disagree) to 7 (completely agree). Both questionnaires were in Finnish as it was the study language of their degree. The scales used in this study are marked in Table 1. Full table of all scales in the questionnaire can be found in Appendix 3.

Table 1. Questionnaire scales used in this study

Scale	Source
Technology / Tool Relatedness	Adapted from Cook & Artino Jr, 2016
Training Relatedness	Cook & Artino Jr, 2016

The Technology/Tool Relatedness and Training Relatedness scales both included nine items, which can be seen from Table 2 below. The used questions were in Finnish.

Table 2. Items in Tool/Technology Relatedness and Training Relatedness scales

Technology/Tool Relatedness	
Item in Finnish	**Item in English**
TER1 Teknologia/työvälineet loivat yhteenkuuluvuuden tunnetta ryhmässä.	TER1 The technology/tools created a sense of togetherness.
TER2 Sain tukea teknologian/työvälineiden käyttöön.	TER2 I received support for using the technology/tools.
TER3 Teknologian/työvälineiden käyttö mahdollisti vuorovaikutteisuutta kouluttajien kanssa.	TER3 Using the technology/tools enabled interaction with the trainers.
TER4 Teknologian/työvälineiden käyttö mahdollisti vuorovaikutteisuutta muiden koulutettavien kanssa.	TER4 Using the technology/tools enabled interaction with other students.
TER5 Teknologian/työvälineiden käyttö mahdollisti konkreettista tekemistä.	TER5 Using the technology/tools enabled concrete action.
TER6 Teknologian/työvälineiden käyttö loi hyvän ilmapiirin.	TER6 Using the technology/tools created a good atmosphere.
TER7 Teknologian/työvälineiden käyttöön liittyi kilpailua.	TER7 There was competition related to the technology/tools.
TER8 Teknologian/työvälineiden käyttöäni kritisoitiin.	TER8 I was criticised of my use of the technology/tools.
TER9 Teknologian/työvälineiden käyttö jakoi mielipiteitä.	TER9 There were diverging opinion regarding the use of technology/tools.
Training Relatedness	
Item in Finnish	**Item in English**
TRR1 Koulutuksessa syntyi yhteenkuuluvuuden tunnetta.	TRR1 A sense of togetherness developed during the training.
TRR2 Tunsin saavani tukea.	TRR2 I felt that I received support.
TRR3 Koulutuksessa oli vuorovaikutteisuutta kouluttajien kanssa.	TRR3 There was interaction with the trainers.
TRR4 Koulutuksessa oli vuorovaikutteisuutta muiden koulutettavien kanssa.	TRR4 There was interaction with the other students.

TRR5 Koulutuksessa oli konkreettista tekemistä.	TRR5 There was concrete action in the training.
TRR6 Koulutuksessa oli hyvä ilmapiiri.	TRR6 There was a good atmosphere in the training.
TRR7 Koulutuksessa syntyi kilpailua.	TRR7 The training resulted in competition.
TRR8 Koin saavani negatiivistä kritiikkiä.	TRR8 I felt criticised in the training.
TRR9 Koulutus jakoi mielipiteitä.	TRR9 The training caused for the opinions to diverge.

5.5 Thematic interviews

The student group interview was conducted as a semi-structured interview (see interview questions in Appendix 1). The group interview questions were developed with the idea of comparing group work in the two lesson types. The themes in the interview included expectations regarding the learning environment (for example *What kind of expectations did you have for the lesson held in the virtual reality?*) and group work in the virtual reality lesson (for example *How well did you succeed working together in the virtual reality lesson compared to the workshop lesson?*). Group interviews were shorter with only a few questions, compared to the pair interview described below.

The teachers were interviewed shortly after student interviews, after the students had left the classroom. The teachers were interviewed following the same themes as the students, though in a more informal way. The teachers' interviews were only used to gain understanding of the learning situations from the teachers' point-of-view. This was important as the data collection was done remotely.

To have more in-depth thoughts from students and to minimise effects of the group in the interview, two students were asked to have a pair interview on a separate day. The conducted interview lasted around one hour. The interview themes were comparison of the two different types of lessons, interaction, stress, feelings, interdependence, and responsibilities. A part of the interview questions was designed to understand how the students experienced cooperative learning. These interview questions were developed with the research group and can be found in Appendix 2.

5.6 Procedure and data collection

The lessons took place in October 2020, March and April 2021 at the schools' own classrooms. In total there were five groups that participated in the study on separate days. See Table 3 for short description of data collection and participants.

Table 3. Data collection description

School	Data collection time	Data collection type	Number of students	Study year of students
University of Applied Sciences	October 2020	At school	14	4-5
Vocational School	March & April 2021	Remotely	21	1-3

In the October session, the research group observed both training situations and made notes at the school's premises. The March and April data collection were done remotely due to the pandemic. On the remote data collection days, the researchers were only present in a video conference call at the beginning of each lesson, and towards the end of the day during the student and teacher interview. An overview of the data collected and used in this study is presented in Figure 7.

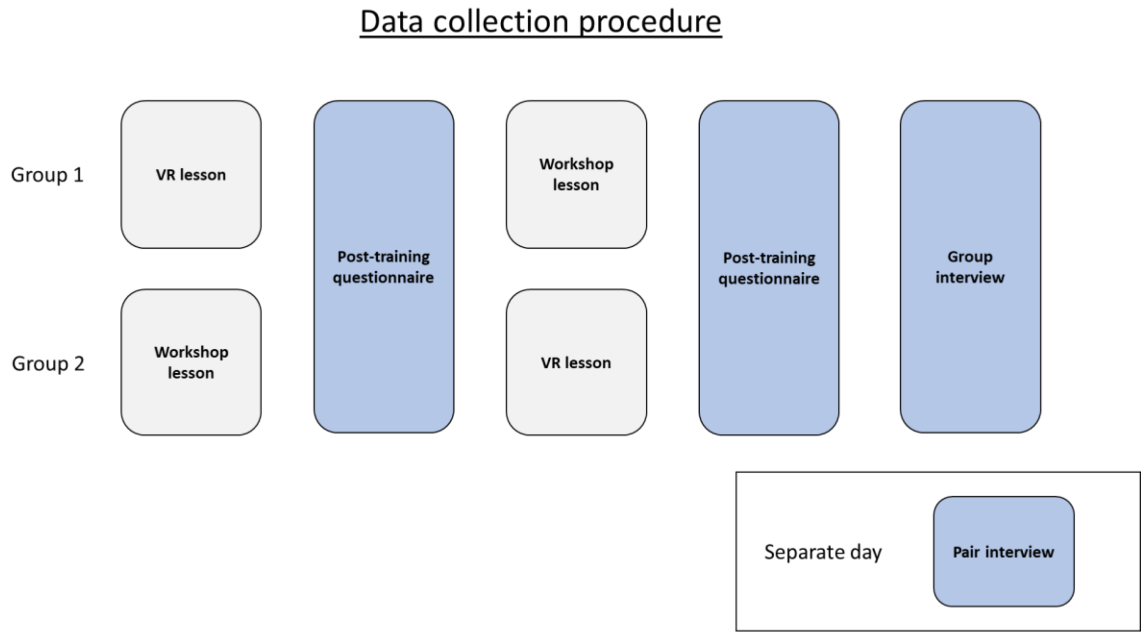

Figure 7. Data collection procedure

On each data collection day, the groups were divided into two, one taking the VR and the others the workshop lesson, except one smaller group was not divided and they followed the lessons together. The group sizes were 3-5 students. The groups switched the training method in the middle of the day, so that everyone would participate in both training methods. The students were asked to fill out two electronical questionnaires with Microsoft Forms, the pre-training questionnaire before and the post-training questionnaire after each lesson (VR or workshop). Participants used computers in a different classroom to answer the questions. These questionnaires are described in the section above5.4.

At the end of each day, the students had a group interview, followed with a teacher interview (see section 5.5 for description of interviews). These interviews were done through a videocall, and the students and teachers were together in the classroom. For the group interview, the student group was sitting by a common table, and the video call computer on a separate table. The group discussed their answers together, and mostly one or two students (usually the ones closest to the screen) gave the final reply to the researchers. One pair interview was conducted a week after the lessons.

This thesis includes group interviews and a pair interview that were conducted in March and April 2021. All interviews were in Finnish. The interviews were recorded on video with Microsoft Teams video-call software, and one group interview and the pair interview were transcribed non-verbatim. From the other group interview, only detailed notes were taken instead of transcribing as the quality of the recoding was not good enough for transcription due to echo and other technical difficulties. Transcription was content-focused, and the interview situation details were not marked as they were not the subject of the analysis. Videos were used only for identifying the speaker, and not used as material for analysis.

5.7 Data analysis

The research data consisted of both qualitative and quantitative material and these were analysed with separate research questions. A summary of research questions, the used data and method can be seen from Table 4. Further descriptions of analyses are described in section 5.7.1 and 5.7.2.

Table 4. Research questions, data and analysis methods

Research question	**1. What kinds of cooperative learning experiences do the students report** **a. when studying with a virtual reality learning tool,** **b. when studying with a physical machine** **c. when they compare their experiences with different tools?**	**2. What kinds of differences can be identified in the experienced relatedness in the two different learning settings?**
Data	Pair and group interviews	Questionnaires Training relatedness & tool/tech relatedness scales
Method	Theoretical thematic analysis	Wilcoxon Signed Ranks Test

5.7.1 Theoretical thematic analysis of interviews

Students' experiences of cooperative learning in two different lesson designs were analysed with theoretical thematic analysis (Braun & Clarke, 2006). Thematic analysis can be conducted either with an inductive way, where themes are formed based on the collected data, or deductive way, where the researcher has a specific theoretical interest in the analysis (Braun & Clarke, 2006). Theoretical approach for analysis was chosen for this study, and it is used to test a known theory in a new context, in this case cooperative learning when using virtual reality learning equipment. The theoretical thematic analysis was based on the cooperative learning theory and its five main categories: positive interdependence, individual accountability and personal responsibility, promotive interaction, appropriate use of social skills, and group processing. In this study, the method was adapted to be more deductive and theory-driven: first, a table of cooperative learning elements was created before the pair interview as a tool for interview notes and analysis. The five elements were put as main categories and below each category were their distinct features (see an example in Table 5). This table is assembled from notes of Leppilampi (2002) about different aspects of each theme. The features were planned to be reviewed if they were mentioned as being fulfilled, not being fulfilled, or not mentioned at all. Then the interview questions were created, partly considering the elements of cooperative learning.

The first stage of the analysis was the transcription process, where also the material was familiarised, and the first remarks were made of how cooperative learning was present in the certain interview. The transcriptions then were read many times to form an overview of the data. Then the students' experiences were coded and classified within the five main themes of cooperative learning according to the literature. Instead of coding and then refining initial themes, as the method suggests (Clarke & Braun, 2013), the themes were taken from existing literature of cooperative learning. Then the codes were refined as different subcategories of each elements, creating the initial results. Then after the subcategories were reviewed, the analysis table was filled to summarise the cooperative learning experiences in the interviews. The codes for the elements of cooperative learning were larger entities and different categories overlapped in the experiences, so therefore the mentions are not quantified in the analysis table. The coding process and classifications were discussed with a peer student of the research group, and the initial analysis was checked and commented by the research group and supervisors. The classifications and initial results were discussed until a shared understanding was reached.

Table 5. Example of cooperative learning theme table

Cooperative learning elements	**Mentioned, fulfilled**		**Mentioned, not fulfilled**		**Not mentioned**	
	VR	**WS**	**VR**	**WS**	**VR**	**WS**
Positive interdependence						
group members need each other for completing the task						
group's success depends on each member's success						
shared success benefits everyone's learning						
motivation for working together						
common rules and goals						

5.7.2 Analysing students' relatedness experiences

The participants filled out technology/tool relatedness and training relatedness scales after each lesson, and these data were analysed with quantitative methods. In this study, the same students responded to the same questions twice, as they evaluated their experienced relatedness after each lesson. The questions were the same but adapted to the context, and students responded either to the VR or the workshop lesson related questionnaire. Students that started with the VR lesson responded to the VR related questionnaire after first lesson, then to the workshop related questionnaire after the second lesson. The students that started with the workshop lesson did vice versa.

The internal consistencies of the relatedness scales were assessed by calculating the Cronbach's alpha value (Cronbach, 1951; Taber, 2018). The Cronbach's alpha values in the technology and tool relatedness scales were .82 (first measure) and .86 (second measure), and for training relatedness .87 (first measure) and .87 (second measure). The reliability was high (> .7), therefore all items were kept in the scale. For further analyses, four sum variables were calculated: the Technology/Tool Relatedness in Lesson 1, the Technology/Tool Relatedness in Lesson 2, the Training Relatedness in Lesson 1 and the Training Relatedness in Lesson 2. Descriptive statistics of the four scales are presented in Table 6.

Table 6. Descriptive statistics of relatedness scales

Scale	M	SD	α
Technology/Tool Relatedness in Lesson 1	4.93	1.00	.82
Technology/Tool Relatedness in Lesson 2	5.08	1.12	.86
Training Relatedness in Lesson 1	5.08	1.01	.87
Training Relatedness in Lesson 2	5.13	1.14	.87

The distribution of the sum values was examined with the Shapiro-Wilk test. The four relatedness scales were normally distributed in both groups (see Table 7 for Shapiro-Wilk tests scores).

Table 7. Shapiro-Wilk tests of normality of relatedness-scales

Scale	Lesson order	Statistic	Significance
Technology/Tool Relatedness in Lesson 1	VR to workshop	.94	p >.05
	Workshop to VR	.92	p >.05
Technology/Tool Relatedness in Lesson 2	VR to workshop	.93	p >.05
	Workshop to VR	.89	p >.05
Training Relatedness in Lesson 1	VR to workshop	.90	p >.05
	Workshop to VR	.92	p >.05
Training Relatedness in Lesson 2	VR to workshop	.90	p = .05
	Workshop to VR	.95	p >.05

These types of measurement are called paired samples. Even though the samples were normally distributed, the group sizes are too small for parametric test requirements (<30). Nonparametric tests are used when the assumptions of parametric tests (parameters) cannot be achieved or the sample size is small (Corder & Foreman, 2014; Dwivedi, Mallawaarachchi & Alvarado, 2017). These assumptions include that the samples are drawn randomly from normally distributed population, measured values are on an interval or ratio measurement scale, and the samples to have equal variances (Corder & Foreman, 2014). Requirements for the paired T-test vary depending on the source.

According to Dwivedi and colleagues (2017), the paired T-test requires only the assumption of normality, but for example according to Nummenmaa (2006), also at least an interval measurement scale is required. In this study, the studied sample is small (*N* = 35), the groups that started with different lessons are even smaller (*n* = 15 & *n* = 18), and the used scale is an ordinal Likert-scale. Therefore, the differences in experiences of relatedness in two lessons were analysed with the nonparametric Wilcoxon Signed Ranks Test, test for comparing two related or paired samples (Corder & Foreman, 2014). In this study, nonparametric tests are used to analyse the differences in relatedness between the paired student groups' responses.

Statistical analyses were performed using IBM SPSS statistics program version 27.

5.8 Trustworthiness and research ethics

The aim of this study was to compare the cooperative learning and relatedness experiences in a lesson with a virtual reality tool to a traditional workshop lesson. The studied sample ended up being quite small for quantitative analysis. A mixed methods study plan was established to complement the scarce quantitative data. Quantitative data of experiences in relatedness were combined to interview data about experiences of learning with the two learning tools. Despite the small sample, the study was able to introduce the theme of cooperative learning and relatedness experiences in students learning with different learning tools.

Part of the data collection was done remotely due to the pandemic, which had some disadvantages. The remotely operated research prevented observation of the lessons. Observation could have given complementary insights to the students' experiences described in the interviews. The group interviews were not of as good quality as they could have been in-person interviews, as it was sometimes hard to hear what the students reported because of echoes in the space. The researcher, presented on the screen, may also have felt distanced compared to a situation where the interviewer was present. One of the groups was joking around a lot, and a longer discussion was harder to establish than with other groups.

To gain a better understanding of students' experiences, a pair interview was arranged few days after the lessons and the group interview. In the pair interview, more detailed questions were asked, and the students were able to describe their feelings without the teachers' presence. The pair interview questions were further developed to get more information about cooperative learning experiences rather than teamwork in general, and lessons were evaluated as a whole, all learning activities included. This helped to give more understanding for answering the first research question.

Unlike the group interview, the pair interview was conducted without the teacher in the room. A pair interview was chosen over an individual interview to create a conversation between the students and to create a safer space for the students to be interviewed. The researchers both asked questions, so it would feel more like a conversation rather than an interview. In all interviews, it was made clear that their replies were only used for research purposes and that their answers wouldn't affect their grades.

This study was conducted by the guidelines of the Finnish Advisory Board on Research Integrity (TENK, 2012). Participation in the research was voluntary for students, and permission to use the questionnaire replies and interview material for research purposes was asked in the questionnaire form and at the beginning of interviews. At the beginning of each data collection day, the research project and its aims were described shortly, and that the data is collected for research purposes only. All collected data was stored in a cloud storage that was under password protection (Microsoft One Drive and Teams). Participants cannot be identified from the published research report.

6 Results

6.1 Cooperative learning with a VR tool

This chapter focuses on the first research question. The chapter describes vocational school students' cooperative learning experiences in using a VR learning tool and how the experiences compare to a conventional workshop lesson.

This section is divided in five categories according to the essential components of cooperative learning: positive interdependence, individual accountability and personal responsibility, promotive interaction, appropriate use of social skills, and group processing. All components are evaluated for the participants' experience in the lesson and how well they were supported in the virtual reality and the workshop lesson designs.

The results of the theoretical thematic analysis are summarised in Table 8 below. The table describes what different elements of cooperative learning were mentioned in the interviews, if they were fulfilled in the VR and/or workshop (WS) lesson or not fulfilled, or not mentioned at all. In general, many of the cooperative learning elements were mentioned in the interview in a positive way. There were some differences in experiences of the two lessons, especially related to communication. Group processing had the least amount of mentions in the interviews, and it was not clear if it was fulfilled in either of the lessons.

Table 8. Cooperative learning experiences as expressed in the interviews

Cooperative learning elements	**Mentioned, fulfilled**		**Mentioned, not fulfilled**		**Not mentioned**	
	VR	**WS**	**VR**	**WS**	**VR**	**WS**
Positive interdependence						
group members need each other for completing the task					X	X
group's success depends on each member's success					X	X
shared success benefits everyone's learning	X	X				
motivation for working together	X	X	X			
common rules and goals	X	X	X	X		
Individual accountability and personal responsibility						
every member did the task or contributed to it	X	X				
everyone responsible for their own learning					X	X

everyone can do the task themselves	X	X				
responsibility for group's success	X	X				
being able to describe the process and decision making					X	X
no free-riders or uneven workload	X	X				
encouraging each other					X	X
looking after each other	X	X				
Promotive interaction						
open communication	X	X	X			
equal possibilities to communicate	X	X	X			
everyone having a possibility to participate in the decision making	X	X	X			
Appropriate use of social skills						
everyone having a possibility to share their thoughts and participate	X	X	X			
leadership skills					X	X
trust	X	X				
valuing each other	X	X				
equality of group members	X	X				
listening to each other	X	X				
negotiating together	X	X	X			
shared decision making	X	X	X			
conflict management					X	X
Group processing						
observing group's activity and reflecting on it	X	X	X	X		
observing teamwork skills development					X	X
observing one's own learning					X	X

6.1.1 Positive interdependence

Five distinctive qualities of positive interdependence were analysed from the interviews: the group needing each other to do their task, the group success depending to each members' success, joint success being beneficial for all learners, motivation for working together, and common rules and goals.

In the pair interview, the students described working together in their group in both lessons, the one with VR equipment and the one with a physical machine. Motivation for working together was created with the paper exercises: when everyone shared what they knew and found, they could ease their amount of work. The paper exercises were done in both lessons, and any differences of working style were not mentioned in the interviews. The students in the pair interview mentioned that they work together a lot in the same group in their studies, so they had gotten used to working together in class.

Common rules and goals were part of the students' way of working. The students in the pair interview described that though the group had not made any clear plans for doing the paper exercises, they shared their answers that they found with their group and received answers from others, so workload was divided. According to them the group did not have to establish any rules or responsibilities, but they believed that everyone did their own part.

> *S1: Well, we did not really divide it, but everyone did that there so there was someone. I believe, I believe that in the meantime for instance to look for information there when someone looks for somewhere else. If I for instance look for information for the first exercise, then the other classmate will look for information for the next exercise. (translated)*
>
> *S1: No, ei me sitä oikein jaettu, että siellä vaan jokainen nyt tehtiin sitä niin siinä oli joku. Mä uskon, mä uskon ton sillä välin vaikka tohon noin tietoa kun joku katsoo johonkin, niin. Kyllä että jos mä vaikka katon ekaan tehtävään tietoa, niin se toinen kaveri kattoo seuraavaan tehtävään tietoa. (original)*

Some students felt that the virtual reality exercises did not motivate for working together as much as the paper exercises. Some students in the group described that dividing tasks in the VR was not possible, because only one could be in control at a time.

> *S6: Well it was a bit harder to divide it (work) there, because there only one could do the work at a time so the others filled out the other stuff that were there and one did the VR thing more. (translated)*
>
> *S6: No siinä oli vähän vaikeampi jaotella sitä (työtä), ku siinähän ei voi tehdä kuin yksi kerrallaan sitä ite hommaa niin sitten muut täytteli sitä noita muita juttuja mitä siinä oli ja yks teki sitä vähän sitä VR juttua enemmän. (original)*

Although the students did not share tasks in the VR environment, there were mentions that they enjoyed the others being there, even though they could not contribute to the work done in VR.

S3: Well, classmates could tell things at the same time and well, for example that which part had to be detached and could follow it from the screen. And and. And such. It made a good, good feeling. (translated)

S3: Tuota, siinä hyvin tuota kaverit pysty kertomaan samalla asioita ja tuota, vaikka että mikä osa pitää irrottaa ja pysty seuraamaan sitä näytöltä samalla. Ja ja. Semmoista. Hyvää, hyvää mieltä siitä tuli. (original)

Even though no one described experiences of being dependent on others in the VR exercises, there were mentions that could be interpreted that they cared about each other's learning. One student described that they did make sure that the one doing the VR exercises cached up with the rest of the group doing exercises on paper. The student felt that the group did not want to disturb the learning situation and helped whenever someone had a problem, with VR or the other exercises.

S1: Umm well of course someone could have disturbed there, but no one really disturbed anyone and you were able to help there, when for instance the first one had played with the VR or the simulator there, so then you could give instructions to the next, that how it works. (translated)

S1: Mmm no tottakai siinä nyt olis voinut häiritä, mutta eipä oikein kukaan häirinnyt ketään ja siinä silleen pysty nyt auttamaan, että siinä kun vaikka ensimmäinen oli käynyt sen VR:llä tai simulaattoria pelaamassa siinä, niin sitten pysty niinku se sille seuraavalle ohjeistaa, että mitenkä se toimii että, niin. (original)

Something that came up that hindered working together in VR was some technical issues that were faced. The camera that recorded the view of the VR user was fast-moving and the view seen on the screen was busy, which made it hard to observe the user's actions. The students also reported that the view was not accurate to the view of the user, as some of the text boxes were not shown complete in the screen or they could not see the full view of the operation being done. This could have motivated the students viewing the screen to look for information elsewhere.

In the workshop lesson, one student could give instructions to the other students when reading the machine manual and other student could perform the maintenance procedures. Although they could help each other with the VR too, the VR environment seemed to encourage for individual work more.

The group needing each other for finishing the task was not mentioned in the interviews, but having more people doing the research for answers and helping with the equipment was beneficial overall. This applies to both lesson designs, as the paper exercises were the same in both of them.

It can be said that there was some positive interdependence that was supported in both lessons, but the attributes supporting cooperation were very much established already earlier in studies. The most interdependence that was described was related to the paper exercises rather than the maintenance exercises done with the physical or the virtual machine. The students did not bring up any differences in interdependence between the VR and the workshop lesson but dividing tasks in the VR exercises were experienced to be more difficult by some students.

6.1.2 Individual accountability and personal responsibility

Individual accountability was analysed with these elements in mind: every member doing the task or contributing to it, everyone being responsible for their own learning, everyone being able to do the task themselves, taking responsibility for group's success, being able to describe the process and decision making, there being no "free-riders" or uneven workload, encouraging each other and looking after each other.

In the students' experiences, task division in both lesson types were considered equal. In the paper exercises, that were done in both lessons, the interviewed students agreed that all students took responsibility, and everyone took part in the information search. The students experienced that everyone did their part also with the exercises with the physical or virtual machines.

When asking if all students learned the same things, the students described that everyone took their turn with the VR that everyone was doing the VR tasks in their turn. Also some students felt that other students were participating because they were talking with the VR user while doing the exercises.

> *S7: I don't know, everyone tried the things there quite as much as others, that quite well it (tasks) was divided anyway. (translated)*
>
> *S7: En mä tiedä, jokainen niitä nyt silleen kokeili aika niinku saman verran, että aika hyvin se (tehtävät) silleen jakautu kuitenki. (original)*

This was the case for the workshop lesson activities with the physical machine:

S1: Well was it now the whole group there watching it and everyone on their turn went to lubricate the grease nipple and, then it was a bit like there we did it together all the time. (translated)

S1: No onko se nyt koko ryhmä siinä katottiin sitä ja jokainen vuorollaan siinä kävi rasvamassa niitä nippoja ja, sitten se vähän niinku siinä koko ajan yhdessä tehtiin. (original)

This also removed the possibility of being a “free rider”, as everyone had to do the same tasks in their own turn in both lessons. On the other hand, it was mentioned that following the screen that showed the VR environment was more passive participation.

S6: It is after all a bit like that with the real machine, maybe the people participate a lot more, that they don’t just follow that (screen) there. (translated)

S6: No onhan se siellä oikean laitteen luona vähän semmoista, ehkä osallistuu paljon enemmän se porukka, että ei vaan seuraa sitä (näyttöä) siinä. (original)

The elements of individual accountability that were not mentioned in the interviews were each student being responsible for their own learning, everyone being able to describe the process and decision making and encouraging each other to succeeding in the tasks. However, it could be interpreted that they felt responsible for their groups’ learning as they helped each other with the exercises and technical issues.

Individual accountability was experienced in both types of lessons, as both lessons required everyone to take part in the learning activities. There were not any major differences when working with either a virtual or a physical machine, as the students took turns with both learning tools.

6.1.3 Promotive interaction

Promotive interaction was analysed from three points-of-view: open communication, equal communication possibilities and a shared decision-making progress. Within both lessons, the students in the pair interview described that all group members had equal possibilities to participate in group’s discussion when working in the paper exercises. Another part of promotive interaction, shared decision making, was also fulfilled in both lessons regarding the paper exercises in their opinion. The interviewees reported that there were not much decision making involved in the lessons, but the decisions related to paper exercises the students did together as a group.

The biggest differences in promotive interaction were related to the practical exercises with the virtual or the physical machine. The conversation with the student in VR was focused mostly on the instructions for the VR tasks and helping with the technical aspects. This conversation included both the other students and the teacher. However, the some of the participants felt that the VR environment isolated the user from the group work slightly. The VR user was not able to see their group members which affected their participation in group discussion.

> *S1: - -. It did have an effect on the conversation, when there weren't, like you could not really see the classmates in the virtual thing, so you could concentrate more to that exercise. And there was of course some small conversations and so on. (translated)*
>
> *S1: - - . Kyllähän se nyt silleen vaikutti siihen keskusteluun, kun ei siinä ollut, niinku kavereita ei silleen nähnyt siinä virtuaalihommassa, niin siihen kyl enemmän keskitty sitte siihen hommaan että. Ja olihan siinä tietenki jotain pieniä keskusteluja tuli ja tolleen noin. (original)*

In this case, the VR environment did affect open discussion in group work negatively, which is essential in cooperative learning. Though, all group members did the VR exercises in their turn, so that did not affect any individual more than another. The VR environment affected the shared decision making too. The students in the pair interview described that the person doing the VR exercises could not participate in discussion and decision making when they had the HMD on, but only copied what others had decided while they were not there.

> *S1: Umm, everyone had the same opportunities, but of course only one person could do the VR there. They couldn't be really joined to the information search. But then what we had done during that time when one was in the VR we of course told to the person, what answers we had found and so. (translated)*
>
> *S1: Mmm, kaikilla oli samanlaiset mahdollisuudet, mutta siinä tietenkin nyt se yks ainakaan sitä VR:ää siinä teki. Niitä nyt ei sinänsä pystynyt siihen tiedonhakuun liittymään. Mutta sitten kyllä mitä nyt siinä kerettiin tehdä, kun yks oli VR:ssä niin sille sitten tietenkin sanottiin, että mitä vastauksia oltiin sinne löydetty ja tolleen. (original)*

In this case, some students felt that the VR environment did not provide them the information they needed for the paper exercises that were returned to the teacher. Although the VR environment included the same machine that was part of the exercises, the students did not use it to find the information they needed. A problem that came up in the interviews was that some of the VR exercises were in a language that they did not have strong skills in (English) and that the information they were presented was not always understood. Few of the students pointed out that they would have preferred the information in the VR to be in Finnish, their first language.

> *S1: - -, the only problem was that it was in English, and I don't know about you but at least I didn't really understand it. (translated)*
>
> *S1: - - , ainoa ongelma vaan oli se, että se oli englanniksi, ja en mä tiedä teistä mutta mä en ainakaan oikein ymmärtänyt sitä. (original)*

The language problem could have influenced negatively not only communication and decision making, but also positive interdependence, if the students weren't able to use the information in the VR for the paper exercises. These problems were not really faced in the workshop lesson, as the teacher spoke Finnish and they had materials in Finnish. Material in Finnish was also available in the VR lesson when the students filled in the paper exercises, which might also have affected the discussion between the VR user and the other students.

The students in the group interview described that the workshop environment increased cooperation with the group members. The physical machine allowed many of the students work at the same time, which they felt that eased the cooperation between them.

> *S5: Well it was like easier in the reality to do like the work, when as we just said when one can only put the glasses on and see the like from their own eyes, in reality people can then like many people can do the work at the same time. (translated)*
>
> *S5: Niin on se niinku helpompi siinä todellisuudessa tehdään niinku sitä hommaa, kun tuossa justiin sanottiin kun yksi vaan pystyy laittamaan ne lasit päähän ja näkemään sen niinkun sen tavallaan niinku omista silmistään, todellisuudessa on voi tehdä sitten niinku monen niinku samaan aikaan sitä hommaa. (original)*

It could be concluded that the VR tool did not support promotive interaction in this situation and lesson design as well as the physical machine. The problems could have existed because there were two different exercises, and the VR exercises were considered more individual work than the paper exercises, and therefore any decision-making made was only related to the paper exercises. The other problem that the students experienced in the VR lesson was that the student with the HMD could not see others which did isolate them from the other group and the conversation. This problem did not exist in the workshop lesson, where everyone could see each other and work together.

6.1.4 Appropriate use of social skills

Analysing appropriate use of social skills experiences included: everyone having a possibility to share their thoughts and participate, practising leadership skills, trust in the group, valuing each other, equality of group members, listening to each other, negotiating together, shared decision making and conflict management.

Many aspects of used social skills were mentioned when describing experiences in both lessons. The students told that they have been working together for a long time in various courses, and it was mentioned that working together was effortless for them. One student described that they divided their tasks and helped each other to do the paper exercises in both lessons.

S1: Well, in the information search in a way that if someone didn't find information for some exercise, then we helped them there. And that it is this and this and so on. (translated)

S1: No, silleen tiedon etsinnässä, että jos toinen ei löytänyt johonki tehtävään vaikka tietoa, nii sitte auttoi siinä että. Ja että se on tämä ja tämä ja niin. (original)

The students in the group interview also experienced that everyone was included in the conversations.

S2: Yes, everyone that was there then did participate in the discussion. (translated)

S2: Joo kaikki, jotka sattu olemaan paikalla silloin niin kyllä siinä keskusteli. (original)

Valuing and trusting each other was also part of both lessons. One of the interviewees shared that student group wanted everyone to complete their work and they did not at least on purpose disturb each other. One student also noted that they were also able to learn from each other, so listening to what the other say was seen valuable. One of the interviewed students described that they trusted that everyone wanted to work together and do their part on the paper exercises.

Describing the VR lesson, one of the students mentioned that they valued the tips that others gave for technical difficulties or in situations where they could not find the searcher part or if they did not know what they were supposed to do next.

> *S5: Well it was maybe nicer in a group, when then when you did it so the others nevertheless saw from the screen what happened there and then could there like at the same time watch and give some tips if you wanted. (translated)*
>
> *S5: Niin no kai se ryhmässä oli mukavempaa, kun sitten kun sä teit sitä niin muut kuitenki näki siitä näytöltä mitä siinä tapahtu ja sitten pysty siinä niinku samalla seuraamaan ja antaa sitten jotain vinkkejä jos halus. (original)*

The interviewees told that the other students had some technical problems when they followed what the person in the VR was doing or reading. The screen that the others viewed the VR environment showed a bit higher up than what the VR person looked at, so the peers did not see all the text that was shown in the VR environment.

The students' social skills were put into practice in both types of lessons, but the technical aspect of VR probably gave a new type situation for cooperation. Something that changed the normal discussion a bit was the fact that the student in the VR environment could not see their peers, which reduced the discussion between them and others. However, the students described that they enjoyed that the others were there to see what they were doing in VR, even though they could not see the others.

One student told that having a conversation was easier in the workshop lesson when everyone could see each other. One student also experienced that cooperating was easier when they could divide their tasks and do things at the same time with the physical machine.

> *S1: Well then (in the workshop) it was easier (to have a conversation), yes. (translated)*

S1: No silloin (työpajassa) oli helpompi kyllä (keskustella). (original)

The interviewees did not share anything related to leadership skills, and no leader roles were taken in any parts of the lessons. However, they said that they worked very independently together without the teacher leading the cooperation. One described that they negotiated their answers to some extent, but they described that there were not much decision-making or problems that needed to be solved. Technical problems were discussed with the whole group.

S1: Umm, we didn't really do any big decisions, that if for instance one classmate looked for information for some exercise so if they gave somewhat right type answers or that they at least sounded right, so then we were like okay we will put that there. (translated)

S1: Mmm, ei me nyt varsinaisesti mitään suuria päätöksiä tehty, että se jos vaikka yks kaveri etti johonki tehtävään tietoa niin sitten jos sieltä tulee niinku ihan semmoset oikeanmukaisia vastauksia tuli sieltä tai ainaki silleen että kuulosti oikealle, niin sitten vaan oli silleen että joo no se sitten siihen niin. (original)

The students' social skills were practiced in both lessons, but the VR environment did have some effect on certain aspects such as negotiating together and decision making. The VR environment and exercises did give a new type of situation for practicing social skills, but it was not seen only in a negative way, as the students mentioned helping each other with the VR environment and enjoying having others in the situation.

6.1.5 Group processing

Group processing was studied from three points-of-view: the group observing their activity, teamwork skills development, and one's own learning.

Group processing did not appear much in the students' experiences of either lessons. The students did not mention if their cooperative work included evaluation of teamworking skills. They also did not describe much about their own learning, and if they took action for improve it during working. One of the students said that they did not discuss or evaluate their teamwork or the way they did their exercises. The cooperation was done the same way all day: looking for information separately and sharing the answers with others.

S1: We did it pretty much the same way from start to finish. (translated)

S1: No aika pitkälle siin samalla lailla alusta loppuun, niin. (original)

However, the students in the pair interview described that most of the time, the group was working independently without the teacher, but in both of the lessons they were able to ask the teacher for help if they needed. This could mean that the students were reflecting on how they were progressing in their learning activities, and asked help in they did not know how to proceed.

Experiences of group processing did not much come up in the interviews, and the only mentions were related to observing their activity and progress, that was both fulfilled and not fulfilled in different ways. Teamwork skills and evaluation of learning were not mentioned.

6.2 Relatedness with different learning tools

This section focuses on the second research question, where the differences of experienced relatedness in two learning settings (lessons with VR tool and physical machine) are examined.

Relatedness was measured after each lesson in the post-training questionnaires, so each student ranked their experiences after the lessons with a physical machine and VR tool. Two measures in the questionnaire focused on relatedness, one was a tool/technology -oriented and the other an overall training situation -oriented.

First, I compared students' tool/technology relatedness experiences and how they differed according to whether they started lesson by practice with the physical machine or with the VR. Student groups' means on the four sum variables of the Technology/Tool Relatedness in Lesson 1 and Lesson 2 and the Training Relatedness in Lesson 1 and Lesson 2 were compared with a Wilcoxon Signed-Ranks Test. The student groups were formed by the order of lessons they started with, i.e. starting with the physical machine or with the VR.

For the student group that started with VR (n = 18), a Wilcoxon Signed-Ranks Test indicated that the median tool/technology relatedness ranks in the second lesson (physical machine), Mdn = 5.11, were not statistically significantly different than the median tool/technology relatedness ranks in their first lesson (VR), Mdn = 5.33, Z = 76, *p* = .363. Nine students (50%) reported higher relatedness related to the learning tool, six students (33%) lower and three (17%) reported the same level of relatedness.

For the student group that started with the physical machine (*n* = 15), a Wilcoxon Signed-Ranks Test indicated that the median tool/technology relatedness ranks in the second lesson (VR), Mdn = 4.67, were not statistically significantly different than the median tool/technology relatedness ranks in their first lesson (physical machine), Mdn = 4.67, Z = 48, *p* = .861. Seven students (47%) reported higher relatedness related to the learning tool, six students (40%) lower and two (13%) reported the same level of relatedness.

Second, I compared students' training relatedness experiences and how they differed between student groups that started with either a VR or a workshop lesson. The Training Relatedness in Lesson 1 and Lesson 2 were compared with a Wilcoxon Signed-Ranks Test.

For the student group that started with VR (*n* = 18), a Wilcoxon Signed-Ranks Test indicated that the medians of the Training Relatedness ranks in the second lesson (physical machine) (Mdn = 5.11) and in the first lesson (VR) (Mdn = 5.11, Z = 103, *p* = .069) did not differ significantly. Ten students (56%) reported higher relatedness in the training, six students (33%) lower, and two (11%) did not experience any change in relatedness.

For the student group that started with the physical machine (*n* = 15), a Wilcoxon Signed-Ranks Test indicated that the medians of the Tool/technology Relatedness ranks in the second lesson (VR) (Mdn = 4.89) and in the first lesson (physical machine) (Mdn = 4.78, Z = 28, *p* = .068) did not differ significantly. Five students (33%) changed to higher relatedness in the training and ten students (67%) changed to lower level of relatedness.

Statistically significant differences in experienced relatedness for two lessons were not found in this data. However, if we look at the positive and negative changes in experienced relatedness, 10 students (56%) reported higher training relatedness when changing from VR lesson to the lesson with the physical machine, and 10 students (67%) reported lower training relatedness than when they changed from physical machine lesson to VR lesson. This could mean that in the students' experiences, the lesson with the physical machine supported relatedness in the group better than the lesson with the VR.

Experiences related to tool/tech relatedness varied. Positive differences when changing from VR to physical machine (50%) seemed to be more common than negative changes (33%), but when changing from the physical machine to VR, there were almost even positive (47%) and negative (40%) fluctuations. Table 9 describes the statistics of changes in experienced relatedness, Figure 8 will visualise the different changes.

Table 9. Changes in experienced relatedness

		Positive difference	Negative difference	No change
VR to machine	Tool/tech relatedness	9 (50%)	6 (33%)	3 (17%)
	Training relatedness	10 (56%)	6 (33%)	2 (11%)
Machine to VR	Tool/tech relatedness	7 (47%)	6 (40%)	2 (13%)
	Training relatedness	5 (33%)	10 (67%)	0 (0%)

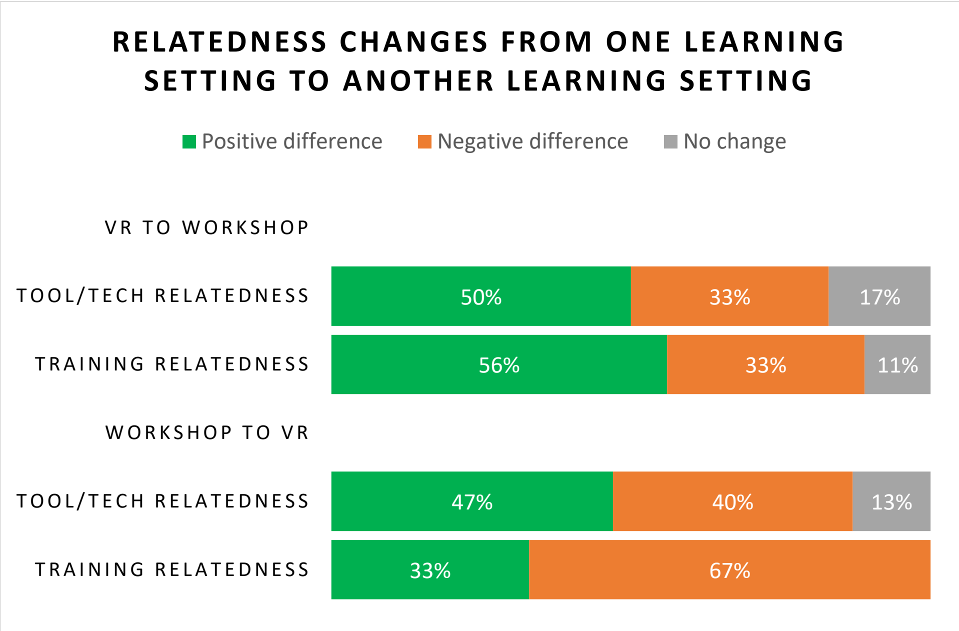

Figure 8. Relatedness changes with different learning tools

The results seem to indicate some differences in experiences of relatedness, but the results are not statistically significant. Discussion on how these results compare to previous research and the experiences described in the interviews is presented in the next chapter.

7 Discussion

Aim of the study

This study compared vocational school and UAS forestry students' cooperative learning and relatedness experiences with two different learning tools, VR and a physical machine. Pre- and post-questionnaires, together with group and pair interviews gave insight to forestry students' experiences in two learning settings. The aim was to find ideas for developing educational design and enhancing learning experiences when sharing a VR learning tool.

Main findings

One of the main findings was related to the students' experience of the VR learning setting as promoting cooperative learning less than studying with a physical machine. The interviews revealed problems related to the learning setting in which the VR device was shared among the group of students. In the VR learning setting the students experienced less positive interdependence than with regard to the VR tool supporting mainly individual learning. On the other hand, individual accountability was supported in both learning settings, as the students felt that everyone did the same things and participated in the lessons equally. VR did not support promotive interaction as efficiently as the workshop lesson, as the VR environment can weaken the conversation between students or group members. These experiences were also connected to the experiences of using and developing social skills. Group processing experiences were not salient in the interviews, so it could not be reported sufficiently from this data.

No statistically significant differences were observed between the two learning settings when comparing students' experiences of relatedness. However, on a closer look at the positive and negative changes of relatedness, it appeared that VR lesson may not have supported students' relatedness experiences as well as the workshop lesson. There were more positive changes in experienced relatedness when changing from VR to workshop lesson, a more negative changes in relatedness in groups that changed from workshop to VR lesson. These results are supported by the experiences described in the interviews, as VR had a negative effect for example on promotive interaction.

The results on the differences in experiences of cooperative learning and relatedness in the two lessons could have also been observed by the positions that the students took in different lessons. In Figure 3 we can see the positioning taken by the students during the VR lesson: one in the middle with a HMD, and the other students standing and sitting around the edges of the room, looking at their screens rather than the student in the middle of the room. If we compare it to a picture from the workshop lesson (Figure 5), where the students stand closer together and look at the same screen, everyone focuses on the same topic. A feeling of being isolated from others when wearing the HMD was mentioned in the interviews, which can negatively affect experiences of both cooperative learning and relatedness. A sense of being cared by others and being part of the group is important for the experience of relatedness (Ryan & Deci, 2017), which might have decreased when wearing the HMD. Isolation from others is also a hinder to promotive interaction, where all group members should be able to communicate with each other with ease.

Succeeding in scaffolding cooperative learning is closely related to lesson structure and design (Johnson et al., 1994a), so the results could be related to the specific lesson designs. Both lessons in the vocational schools had a practical part with either the physical machine or VR as well as an exercise sheet to be completed. The students might have been distracted from working together with the person in the VR when they also had to take time to do the exercises by completing the exercise sheet, decreasing communication within the entire group. The situation could have been different if the exercises in VR and completing the exercise sheet had been integrated, promoting working together with the person in the VR.

The results may have dependant on the devices and application used. There are many different VR devices and applications, and only one was tested in this study. The students and teachers mentioned that there were some technical issues that influenced the experience, such as a fast-moving and shaking view on the screen and the view being slightly different on the screen compared to that on view that the one wearing the HMD had. Poor usability can negatively affect cooperation when using virtual tools (Wagner et al., 2006).

One of the recommendations in literature related to cooperative learning is forming long-term groups that cooperate for longer periods of time (Johnson et al., 1994a). This was the case of the students, as they had already studied and worked together quite extensively previously. Although there are different methods to increase positive interdependence even during a single lesson, building good peer relationships and efficient cooperation is a longer process, and therefore the learning equipment and tools that are used might not play a big role in building relationships. In this research case, the

VR learning tool seemed to encourage more individual work, but positive interdependence was experienced both fulfilled and not fulfilled in the lesson.

Limitations of the study

The results of this study suggest that virtual reality might not support cooperative learning and relatedness as well as a more traditional learning setting. However, this study has some limitations concerning data collection and the size of the sample. The data collection was planned to be performed in multiple educational institutions in forestry-related subjects, and to include questionnaire data, interviews, 360-degree video material, observation and sensory data. Unfortunately, due to the pandemic, the data collection process was postponed, and some data were not collected by observing and interviewing the student groups using both VR and a physical machine in a physical classroom setting. Instead, the researchers were not able to observe the classroom situations and student groups were interviewed through the Microsoft Teams videoconference system.

Due to the small sample, it is uncertain whether the results represent experiences of the students at large. A pair interview in the physical classroom worked better than a group interview for remote data collection, so the analysis of the interviews is restricted mainly to the pair interview. Therefore, the results highlight different experiences that students reported, but the experiences may not apply to the whole student group. The experiences of cooperative learning are only reported from vocational school students' point-of-view, as UAS students were not interviewed about the topic.

In this study, no statistically significant differences were found as for the changes of experienced relatedness between the two lessons, but it seemed that there were more negative changes in changing from workshop to VR and more positive changes when changing from VR to workshop. The results should be interpreted with caution.

There were some limitations related lesson settings, such as applied technology and applications in this study. Some technical difficulties were mentioned related to the learning application and devices, which may have had an effect on the students' experiences of cooperation and relatedness. Also, some students addressed an issue with the language of instruction and understanding. They described that the VR environment would have been better in Finnish, which is their first language. The language of instruction in the lessons was Finnish, but one of the two guided tasks in VR was in English. The language issue might have caused negative feelings for the VR environment and a feeling of not grasping the information that was taught. Learning in a foreign language has been found to weaken learning results as it creates more cognitive load as learning a foreign language and content can overload the working memory (Roussel, Joulia, Tricot & Sweller, 2017). Cognitive load could have been the issue to the experiences of not learning the content as well in the English instruction during VR compared to the Finnish instruction. As immersive VR can itself cause distracting cognitive load (Frederiksen et al., 2020), a translated virtual instruction would be very important for supporting learning. The students also described that they needed to learn the controls of the VR tool first before focusing on the learning content, which can have also increased cognitive load.

Suggestions for future research

As there seems to be only few studies that investigate cooperative learning and relatedness with VR learning tools, this study could open a discussion about developing good practices of lesson design with a VR learning tool. Furthermore, it seems that there are not a lot of studies on relatedness when learning using VR learning tools and the results in this study are unclear, so more research should be conducted in this topic. A larger sample could also give more reliable results. This study could be enhanced by observing the student groups working and evaluating their cooperation. The study was conducted from the perspective of students' experiences, but observation could give attention to subconscious actions and procedures.

This study was not able to highlight the students' experiences of group processing and its differences in the two learning settings. A more in-depth interview about aspects of group processing could give more information about students' experiences. The teachers are also an important part of group processing, and they could have an interesting perspective and could evaluate the students from an outsider perspective. Group processing is also dependant on the lesson design choices, and it requires time reserved for that action. Future research could evaluate how group processing can be supported when sharing a VR learning tool during a lesson.

Though the research on virtual reality learning tools has been criticised for focusing on the usability rather than learning outcomes (Radianti et al., 2020), poor usability can affect the pedagogical design negatively. The technical issues can disturb collaboration, as seen for example in Wagner and colleagues' (2006) study. Future research should consider how much of the cooperative learning and learning outcomes are affected by usability issues. Also, it has been shown that women experience more motion sickness in virtual reality compared to men (Munafo et al., 2017), and the VR equipment is not well designed for women's needs (Stanney, Fidopiastis & Foster, 2020). Stanney and colleagues (2020) found that interpupillary distance (IPD) non-fit was the main reason for gender-differences in cybersickness, and when women were able to adjust the correct IPD they experienced cybersickness evenly with men. As these gender-differences have been found related to usability of the technology, future research should also study cooperative learning and relatedness experiences with both females and males to see if there are gender differences in experiences.

Next, some implications and development ideas brought up by the results of this study and existing literature are discussed.

Implications for educational design

Virtual reality can support many aspects that have a positive effect on learning, such as motivation, participation, and interaction (Wang et al., 2018). Also supporting relatedness has been found to increase motivation and academic achievement (Beachboard et al., 2011). In this lesson design, where the VR tool was used with a screen that showed the VR environment to the ones not wearing the head-mounted device and with a paper exercise added, it seems that VR did not support relatedness as well as the workshop lesson with a physical machine. Though there were no statistically significant changes in the relatedness experiences, it seemed that for many students, the feeling of relatedness was inferior when changing from VR to workshop, and it was more visible with regard of training relatedness rather than relatedness in terms of the tool/technology. This could mean that the lesson design is more important than the tool used, and teachers should focus on supporting dimensions that promote experienced relatedness in the lesson design.

Experiencing two different kinds of lessons during the same day could give us insight on planning a correct time to use VR during the course or along the learning trajectory. When comparing the changes of experiences in Training Relatedness and Tool/Technology Relatedness, 67% of students reported that their experienced relatedness was inferior when changing from workshop to VR lesson. The pedagogical design and the alignment of conventional vs. VR-supported learning settings has not been studied excessively, so these results suggest that the VR lesson could work better when used as an introduction rather than a review of what has been learned.

Experiences of relatedness are established for example by a feeling of being cared for by others, supporting others, and frequent interaction (Baumeister & Leary, 1995; Ryan & Deci, 2017). For supporting relatedness in a group with one wearing a HMD and the other students following the activities on the screen, meaningful ways of communication and supporting the person with the HMD should be structured as a part of the learning tasks. The person with the HMD should feel that the other group members are still there and that they are not alone with the VR tasks, while in this study it was mentioned that the VR environment felt isolating. There could be ways of sharing tasks related to VR, for example that the students would work together to find answers from the VR environment to the on-paper exercises, instead of external resources. Then the students could give suggestions to the peer wearing a HMD for what they should do next and look at the same material at the same time, like during the workshop lesson.

This could also help structure a positive interdependence in the lesson. Positive interdependence can be integrated to a lesson in many ways, but I think that positive resource interdependence and positive role interdependence could fit in this situation of asymmetric collaboration. With resource interdependence, the teacher could diverge the needed material for both the VR and other resources so that the students would need to communicate about the information in the VR environment, and not only manuals and other external resources. Then all group members would be part of information search and they would have more motivation for working together with the person wearing the HMD.

Working towards the same goal could be eased if the teacher assigned different roles to the participants (positive role interdependence). In this study, some of the students felt that it was difficult to assign the tasks in VR as the others without an HMD could not interact with the environment and the virtual machine. To improve the situation, someone could be for example the one that leads the action, writes down answers, checks everyone's understanding or marks down topics that need more elaboration. Then everyone could work together and know what they are expected to do. This could also reduce the feeling of isolation and increase experienced relatedness. The role of a leader could also give an opportunity to practice leadership skills, which is included in the cooperative learning element of practicing social skills.

Positive interdependence supports promotive interaction and practicing social skills by providing them a meaningful context (Johnson et al., 1994b). Cooperative learning emphasises practicing social skills for more efficient groupwork (Johnson et al., 1994a).

The students’ experiences showed that virtual reality did not give that much support for practising social skills in this lesson design compared to the conventional way of teaching in the workshops; on the contrary, it sometimes isolated the VR user from the rest of the group. However, virtual reality as a tool could give the students experiences of working and cooperating in different kinds of situations, for example distance learning. Teachers can structure practicing social skills in the lesson with different tasks, but it is also important to give feedback and allow students to reflect on how these skills could be improved.

Students rarely mentioned experiences related to group processing. It could mean that it was not integrated in the lesson plan or instructed to be done in either lesson. Group processing could provide the teachers with information on how the cooperation is perceived during certain lessons, and it could be beneficial for both the teacher and the students. Group processing can summarise to the lesson and goals for the next lesson, a final step in a cooperative lesson.

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Appendices

APPENDIX 1 GROUP INTERVIEW QUESTIONS

Virtuaalitodellisuuden asenteet

- Millaisia ennakkokäsityksiä sinulla oli virtuaalitodellisuudessa pidettävästä opetustunnista? (helppoa/vaikeaa/kivaa/uutta)
- Miten nämä ennakkokäsitykset toteutuivat? Oliko sellaista kuin kuvittelit?

Virtuaalinen ryhmätyö ja työn järjestely

- Millaista ryhmätyöskentely oli virtuaalitodellisuutta hyödyntävässä opetuksessa?
- Miten ryhmätyöskentely virtuaalikoulutuksessa onnistui verrattuna työpajaan?
    - Yhteistyön sujuvuus
    - Vuorovaikutus, paljonko tarvitsi selittää
    - Työskentelyyn käytetty aika
- Miten työskentely jakautui ryhmäläisten kesken?
- Millainen rooli oli virtuaalilasit päässä olevalla? Entä vierestä seuraajilla?
    - Toimiko joku selkeästi ohjaavasti/johtajana
- Kuinka hyvin virtuaalitodellisuus tukee ryhmäläisten tasapuolista osallistumista työskentelyyn?
- Olisitko tehnyt mieluummin yksin?
- Millaisena näet virtuaalitodellisuuden mahdollisuudet tulevaisuuden opetuksessa?

APPENDIX 2 PAIR INTERVIEW QUESTIONS

Toiminnan kuvaus

- Kerro/kuvaile, mitä teit VR-ympäristössä.
- Mikä oli roolisi, olitko lasit päässä vai seurasitko näytöltä?
- Mikä oli VR-ympäristössä opiskelun tavoite?
- Miksi VR-ympäristöä käytettiin?

Pyydetään haastateltavaa piirtämään kuva opiskelutilanteesta ja esittämään se haastattelijalle.

- Esittelisitkö kuvassa esiintyvät asiat?
- Mihin sijoittaisit itsesi ja ryhmäläisesi tilassa?

Jos haastateltava ei halua/voi piirtää:

Esitetään tilanteesta tehty kaaviokuva haastateltavalle, jossa on esitettynä tilanteen toimijat sekä työvälineet (VR-lasit, näyttö, tehtäväpaperi)

Fyysinen ympäristö vs. osittain virtuaalinen ympäristö

- Kerro, miten teit osien irrottamisen VR:ssä.
- Kerro, miten teit osien irrottamisen fyysisessä ympäristössä.
- Miten se sujui?
- Mikä tuntui helpolta?
- Mikä tuntui vaikealta?
- Miltä opiskelu virtuaalitodellisuudessa tuntui? / Miltä tuntui seurata työskentelyä virtuaaliympäristössä?
    - Miten opiskeluympäristö ja opiskeluvälineet vaikuttivat opiskeluun?
- Miten se erosi fyysisestä ympäristöstä?
- Millaisia hyviä puolia huomasitte näissä eri opiskeluympäristöissä?
- Kumpi toimi itsellesi paremmin?
    - Mikä auttoi oppimaan siinä ympäristössä?
    - Mikä herätti kiinnostusta? Mikä innosti?
- Miten parantaisitte näitä kumpaakin opiskeluympäristöä?

Vuorovaikutus ja toiminta ryhmässä

Voit vertailla VR-ympäristössä työskentelyä ja konehallia vastauksissasi.

- Millä tavoin toimit muiden kanssa tehtävää tehdessä?
- Miten muut toimivat?
    - Muutitteko toimintatapoja tehtävän tekemisen aikana?

        - Miksi, miksi ei?
- Miten opettaja ohjasi ryhmän toimintaa?
    - (erosiko VR ja konehalli)
- Kertoisitko keskustelustanne työskentelyn aikana. (VR vs konehalli)
    - Millaista keskustelu oli?
    - Mistä asioista keskustelitte?
    - Miten kuvailisit ryhmänne jäsenten osallistumista keskusteluun?
    - (Oliko keskustelussa eroa riippuen siitä, oliko opiskeluympäristönä VR- tai konehalliympäristö?)
    - Millaisena koit virtuaaliympäristön vaikutuksen keskusteluunne?
    - Millaisena koit konehalliympäristön vaikutuksen keskusteluunne?
- Kerro tehtävien tekemisestä ja ratkaisemisesta.
    - Yksin/yhdessä
    - Miten kuvailisit ryhmänne työnjakoa?
    - Miten teitte tehtäviä koskevia päätöksiä?
- Kohtasitteko VR-ympäristössä ongelmia?
    - Miten ratkaisitte näitä ongelmia?

Tuntemukset

- Oliko jotakin, mikä ilahdutti tai jotakin, mikä ärsytti tehtävien tekemisen/opiskelun aikana?
- Miten kyselyihin vastaaminen vaikutti oppimiseen?
- Millaisina koitte lomakekyselyt?
- Ilmaantuiko pahoinvointia VR-ympäristössä?

Stressi

- Miten tärkeänä koitte ohjaajan panoksen työskentelyn aikana?
- Miten helppona näit avun pyytämisen muilta opiskelijoilta, jos olisit tarvinnut apua?
- Pystyitkö vaikuttamaan omaan ajankäyttöösi opiskelun/tehtävien tekemisen aikana?
    - Oliko tahti liian hidas tai nopea, vai oliko eteneminen sopivaa?

Keskinäinen riippuvuus ja vastuu

Mieti opetustilannetta, jossa työskentelitte ryhmänä virtuaalisen laitteen kanssa.

- Kerro tehtävien annosta ja miten lähditte tekemään tehtäviä.
    - Miten suunnittelitte työskentelyänne ennen työskentelyn aloittamista?
    - Millä tavalla ryhmätyöskentely ohjeistettiin?
- Minkälaiset olivat eri ryhmäläisten mahdollisuudet osallistua tehtävään liittyvän tiedon etsimiseen ja löytämiseen?
    - Erilaiset/samankaltaiset
    - Eroaako tämä jotenkin työpajassa työskentelystä?
- Miten tehtävät jaettiin ryhmän kesken?
    - Miten päädyttiin tähän ratkaisuun?
- Minkälainen ilmapiiri ryhmässäsi oli?
- Miten toimit toisten apuna?
- Kertoisitko vielä siitä, miten koet oman toimintasi vaikuttaneen ryhmäläistesi opiskeluun.
- Mitä opitte työpajan aikana?
    - Minkälaiset ennakkotiedot teillä oli ennen työpajaa?
    - Oliko virtuaalitodellisuudella vaikutusta siihen, että kaikki oppivat samat asiat?
- Mitä opit ryhmäläisiltäsi?
    - Mitä opit muiden ryhmien jäseniltä?

Lopuksi

- Haluaisitko kertoa vielä jotain aiheeseen liittyen, jota et vielä aikaisemmin maininnut haastattelussa?

APPENDIX 3 SCALES OF PRE- AND POST-TRAINING QUESTIONNAIRES

Scale	Source	Q: 1 or 2	Examples of items in English	Examples of items in Finnish
Motivation	Vallerand et al., 1992	1 & 2	*I believe that this training will help me advance in my career.* *This training is/was enjoyable.*	*Uskon että tämä koulutus auttaa minua eteenpäin urallani.* *Tämä koulutus on/oli kivaa.*
Technology / Tool Autonomy	Cook & Artino Jr, 2016	2	*I had the opportunity to choose how I used the technology/tools.* *My learning was enhanced by using the technology/tools.*	*Minulla oli mahdollisuus valita kuinka käytin teknologiaa/ työvälineitä.* *Teknologian/työvälineiden käyttö edisti oppimistani.*
Technology / Tool Competence	Cook & Artino Jr, 2016	2	*Using the technology/tools was not too difficult.* *Using the technology/tools I got instant feedback of succeeding.*	*Teknologian/työvälineiden käyttö oli sopivan haastavaa.* *Teknologian/työvälineiden avulla sain välittömän palautteen onnistumisesta.*
Technology / Tool Relatedness	Cook & Artino Jr, 2016	2	*The technology/tools created a sense of togetherness.* *Using the technology/tools created a good atmosphere.*	*Teknologia/työvälineet loi yhteenkuuluvuuden tunnetta ryhmässä.* *Teknologian/työvälineiden käyttö loi hyvän ilmapiirin.*
Training Autonomy	Cook & Artino Jr, 2016	2	*I had a possibility to do the training in my preferred way.* *I felt I was learning in the training.*	*Minulla oli mahdollisuus suorittaa koulutusta omalla tyylilläni.* *Koin oppivani koulutuksessa.*
Training Competence	Cook & Artino Jr, 2016	2	*The training was not too difficult.* *I got feedback on my successes during the training.*	*Koulutus oli sopivan haastavaa.* *Sain koulutuksen aikana palautetta onnistumisistani.*
Training Relatedness	Cook & Artino Jr, 2016	2	*A sense of togetherness developed during the training.* *There was a good atmosphere in the training.*	*Koulutuksessa syntyi yhteenkuuluvuuden tunnetta.* *Koulutuksessa oli hyvä ilmapiiri.*

Presence	Witmer et al., 2005	2	*I had the possibility to work actively in the physical space.* *I was able to observe the environment in detail in the physical space.*	*Minun oli mahdollista toimia aktiivisesti fyysisessä tilassa.* *Pystyin havainnoimaan ympäristöä tarkasti fyysisessä tilassa.*
Engagement	InSitu, Vasalampi et al., 2016	2	*I was active.* *I liked the subject of the training.*	*Olin toimelias ja aktiivinen.* *Pidin koulutuksen aiheesta.*
Flow	Vlachopoulos et al., 2000	2	*Doing the exercises felt natural to me.* *I was easily able to concentrate in doing the exercises.*	*Tehtävien tekeminen tuntui minusta luontevalta.* *Pystyin helposti keskittymään tehtävien tekemiseen.*
Teacher efficacy	Ohio State teacher efficacy scale (OSTES), Tschannen-Moran & Hoy, 2001	2	*The trainer gave clear goals to the training.* *The trainer led the training well.*	*Kouluttaja antoi koulutukselle selkeät tavoitteet.* *Kouluttaja ohjasi koulutustilannetta hyvin.*

Q = questionnaire

The scales used in this thesis are highlighted.

APPENDIX 4 OPEN-ENDED QUESTIONS IN THE PRE- AND POST-TRAINING QUESTIONNAIRES

Prior knowledge of the learning material was measured with two open-ended questions in the pre-training questionnaire. The same questions were asked in the post-training survey to see how much the students retained information from each lesson. The questions were:

1. List as many boom parts as you remember or know (max. 20 most significant parts). Describe also their principal functions. For example, chain saw: cuts the wood, etc.
(Luettele niin monta hakkuupään osaa kuin muistat tai tiedät (max. 20 merkittävintä osaa). Kuvaile myös kaikille listaamillesi osille pääasiallinen toiminto. Esim. ketjusaha: katkaisee puun, jne.)
2. List as many colour-marking equipment parts as you remember of know (max. 5 most significant parts). Describe also their principal functions. For example, tank: stores the colour, etc.
(Luettele niin monta värimerkkauslaitteiston osaa kuin muistat tai tiedät (max. 5 merkittävintä osaa). Kuvaile myös kaikille listaamillesi osille pääasiallinen toiminto. Esim. säiliö: varastoi väriaineen, jne.)

Students' teachers graded students' answers. Question 1 and 2 were marked in a scale from 0-5 depending on how many parts were mentioned and how well their functions were described.

The post-training questionnaire also asked the students to analyse their performance with three questions:

3. What mistakes did you do during training and where did you succeed?
(Mitä virheitä teit harjoitussuorituksen aikana ja missä koit olevasi hyvä?)
4. If you made mistakes, did you have a chance to fix them? How did you fix your mistakes?
(Jos teit virheitä, niin oliko sinulla mahdollisuus korjata niitä? Miten korjasit virheesi?)
5. How could you improve your performance?
(Kuinka voisit parantaa omaa harjoitussuoritustasi?)

Two grades were given from question 3, that were marked in a scale from 0-1. First grade was given based on if the student described any mistakes, 0 having no mistakes mentioned and 1 having some mistakes mentioned. The second grade was given in a scale from 0-1 based on if they reflected on their skills, 0 having no reflection and 1 having some reflection on their skills. Question 4 was marked based on if they reflected on how they could fix their mistake, 0 having no reflection and 1 having some reflection on the mistake. Question 5 was marked from 0-1, based on if they gave any ideas on how to enhance their performance.