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Measuring Intragroup Dynamics in an Elementary School Setting Using Mobile Devices

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ABSTRACT

The aim of this thesis is to track and study the changes in intragroup dynamics during an authentic collaborative project at elementary school. The main focus is to study the impact of group members' geographical proximity on intragroup dynamics. In addition, by implementing methods that capture group members' collaboration-related experiences, the study discusses how mobile instrumentation and Experience Sampling Method (ESM) combined with the location tracking data can enhance teachers' understanding of their students' intragroup processes. The specific research questions are: (1) How do different groups experience collaboration in the course of the project work?; (2) Are there any discrepancies between teacher observations and student self-reflection via ESM?; (3) How is the impact of geographical proximity on intragroup dynamics visible in the data collected via mobile devices, instrumentation, and sensors? The participants of the study were students from the 5th grade ($n = 15$, age 10-11, 60% male) from Oulu University Teacher Training School. In this study, the mobile devices, which were using AWARE middleware framework for mobile sensing and were given out to every participant, functioned as the main tool for multi-source data collection, set to track collaboration-related intragroup processes. The data was collected from three different sources, namely (1) student self-reports obtained via mobile devices using the Experience Sampling Method (ESM); (2) RSSI location data for individual student localization purposes along the whole duration of project work; (3) qualitative data from the semi-structured face-to-face interview with the classroom teacher. The results show that all of the groups experienced collaboration differently due to not being equally successful with the project. ESM data analysis results show that the level of success influenced intragroup dynamics of all the groups the most, and impacted the students' level of willingness to continue working together and degree of importance of the project work. 5 discrepancies between teacher interview data and student self-reflection via ESM were found (enjoyment of working together, the influence of low achieving pupils on intragroup dynamics and students' motivation level). The geographical proximity of students had an impact on intragroup dynamics, as the data analysis shows students had influenced the rest of the group members and, as a consequence, project work's success and outcome both positively and negatively by being physically present in the group. The paper contributes to the issue of using the mobile devices and instrumentation in the classroom for research purposes. It argues that the usage of mobile devices and instrumentation in the classroom could provide the teachers and researchers with new insights into the classroom-related processes, and discusses both the technical and social obstacles unique to this context. Such obstacles should be taken into an account before and during the data collection as well as at all stages of data analysis. Moreover, the used approach can be utilized in future research designs and by class teachers in classrooms to gather information on students' learning progress and difficulties.

Keywords: intragroup dynamics, mobile devices, ESM, experience sampling method, collaboration, elementary school, mobile sensing, geographical proximity, teacher interview, project work, group work, classroom

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1 INTRODUCTION

Finland is universally recognized for its effective, forward-thinking and successful education system which never stops developing and evolving (Bastos, 2017; Ministry for Foreign Affairs of Finland, 2017). In autumn 2016, the Finnish schools started working according to the new curricula, created after the country completed the reform of the National Core Curricula for pre-primary and compulsory basic education in December 2014. The new curricula highlight the importance of collaborative classroom practices and the necessity to prepare people for future working life by enhancing the students' entrepreneurial and social skills (Curriculum Reform 2016), which include collaboration and co-operation know-how, crucial for the consolidation of pupils' abilities to properly function in various groups and take responsibility for both their own and common work. According to Roschelle & Teasley (1995, p. 70), collaboration can be defined as a "coordinated, synchronous activity that is the result of a continued attempt to construct and maintain a shared conception of a problem", which makes it an activity the degree of success of which is not easy to measure. Thus, it is necessary to find more ways to capture data from collaborative sessions and understand what influences the collaborative processes the most in order to gain the understanding how to create the environment in which collaboration can blossom. Collaboration is an important skill taught in all levels of education, often through the use of practical real-life projects (Ronfeldt et al, 2015; Sahlberg, 2009). As such, it has become an integral part of the curriculum in Finnish elementary schools. Measuring the degree of a successful collaboration is often challenging due to the dynamicity of the phenomenon. Besides, simultaneous monitoring of student groups is practically impossible. Thus new approaches to data collection and monitoring students are needed.

This study is an early experiment on using mobile devices and instrumentation, where instrumentation is by definition "a collection of instruments regarded collectively" (Ferreira, 2013, p. 39), to trace and measure intragroup dynamics, which denotes the processes happening among the group members inside one team and has a direct impact on collaborative processes and team outcomes (Klug & Bagrow, 2016), in a real and unpredictable classroom environment by gathering multi-source data and comparing that data for differences (student self-reports obtained using the Experience Sampling Method

(ESM) research methodology; location data for individual student localization purposes along the whole duration of project work; qualitative data from the semi-structured face-to-face interview with the classroom teacher).

The data collection for this study took place during the intervention carried out in a real elementary school along the project called “Tämä toimii!” (“This works!”). The goal of “This Works!” was to improve understanding of human being in the world of technology, and to increase children’s interest in technological subjects (LUMA.fi: Tämä toimii!). In this case, the project provided 5th graders (10-11 in age), separated by the teacher into the groups of 4 people, with a demanding, collaborative task of conceptualizing and creating a functional prototype of a movable educational toy and self-documenting the progress.

For the purposes of our study, the elementary school administration allowed us to equip and follow a classroom of four groups over the course of 3 individual 4-hour sessions, lasting over 3 weeks.

The data for the study was obtained using the Experience Sampling Method (ESM) research methodology, measuring different dimensions of human experience – what do people feel, do and think – in the course of their normal everyday lives via asking the participants to provide the systematic self-reports throughout the whole duration of their project work (Csikszentmihalyi et al., 1993; Larson & Csikszentmihalyi, 2014). ESM questionnaire we used consisted of 8 questions and was based on the questionnaire developed by Csikszentmihalyi et al. (1993), as it had already been successfully used in the studies of a similar nature (Peterson and Miller, 2004; Simpson, 2011).

Each of the participants was given own mobile device to respond to the ESM questionnaire. The responses were collected with the plug-in developed for AWARE middleware framework for mobile sensing, locally developed in Oulu (Ferreira, 2013).

Besides, each of the devices was also connected to one of the installed beacons for individual student localization purposes along the whole duration of project work. The goal was to track students’ locations at all times and study if there’s a visible impact of the geographical proximity, “spatial distance between actors” (Boschma, 2005, p. 63), on

intragroup dynamics (for instance, level of stress) and on students' degree of willingness for working together (collaborating) with other pupils.

The intervention was designed in a way that both the ESM and location data was collected using the same devices (each of the participants had only one device instead of having multiple ones). The goal behind this was to use a minimum amount of tools to avoid interference, keep the atmosphere of the project work intact and minimize pupils' distraction.

In addition to the ESM and location data obtained via mobile devices and instrumentation, we obtained the qualitative data from the semi-structured face-to-face interview with the classroom teacher conducted right after the project work was finished. The teacher was present during the whole duration of the project work. We compare the data obtained from the teacher interview to the data obtained via ESM questionnaires from the pupils and state the findings.

The study also discusses the research design of the intervention by describing it and discussing how mobile devices can be used to sense and track human behavior and student progress in an elementary school setting, and which accompanying challenges can the teachers and researchers come across.

This paper contributes to the issue of using the mobile devices and instrumentation in the classroom for research and student progress tracking purposes. Using mobile technology for research is relatively fresh, challenging and unexplored topic, thus there's still a lot of room for exploration (Pinter, Toninelli & de Pedraza, 2015).

2. THEORETICAL FRAMEWORK

2.1 Intragroup dynamics and collaboration

Collaboration has been widely acknowledged as a highly valuable phenomenon in our working and personal lives alike, which can be defined as a mutually beneficial working relationship, which depends on trust, shared vision, objectives and responsibilities, and communication, initiated to achieve common goals (Mattesich et al., 2001). It has a potential of leading people and teams to innovative solutions and the faster way to acquire and digest knowledge, share expertise and validate the ideas (Trilling & Fadel, 2009). Both companies and individuals are embracing the value of having more than one mind tackling a problem, more than one mind developing and fine-tuning the idea, and more than one pair of hands bringing a certain idea to life (North & Kumta, 2014; Simonton, 1988; Weisberg, 2006). The potential is out there for the taking, thus companies and individuals embrace it more and more while the researchers aim for finding more ways to make the collaboration successful, fruitful and fully understand how to create the environment and the conditions, where collaboration can really blossom (Näykki, 2014). In other words, finding keys to collaboration is still a work in progress and would always be, as many new environments where collaboration is possible are appearing every day.

A good team can unlock the potential of collaboration. The power of a good team working together should never be underestimated, as a fine-tuned and well-structured teamwork can lead to a much bigger impact than the work of an individual (Simonton, 1988; Weisberg, 2006). According to Mattesich et al. (2001), factors influencing collaborative projects' success are related to the environment, membership characteristics, process and structure, communication, purpose, and resources. It means that mutual respect among the team members, ability to compromise, flexibility, clear understanding of the roles and responsibilities, open communication, shared vision, sufficient resources, and funds all influence the success of collaborative projects (Mattesich et al., 2001). All of the 6 factors stated above should be represented and paid attention to, and prioritizing only a few of those factors will hold the collaboration back and put a strain on it. Factors define the degree of collaboration success of the whole team – group composition with respect to ability (groups with the most narrow ability range tend to be more successful) and gender

(percentage of male and female members), student characteristics and task characteristics (Lai, 2011).

The important phenomenon defining the process of group work is *group dynamics*, which denotes the processes happening among the group members (Toseland, Jones & Gellis, 2004). In this paper we're focusing on *intragroup dynamics*, which denotes the processes happening among the group members inside one team, having a direct impact on collaborative processes and team outcomes (Klug & Bagrow, 2016).

Today's businesses and organizations increasingly encourage teamwork and structuring the work around it, thus it's more important than ever for students to start understanding group processes as soon as possible (Stewart, 1999). Also, the collaboration should be conscious, which means that the participants should understand their own roles and behaviors within groups (Norton, 2008). The sooner the conscious collaboration starts – the better the skills of the person will be by the time he or she enters the working life.

Those points suggest that the teachers should be able to create the favorable environment for collaboration by supporting students, creating the teams which would be able to work together, being able to study and track their students' progress and addressing and solving challenges emerging along the way.

2.2 Proximity and collaboration

Proximity has an impact on working together, collaboration, learning, creation, innovation and knowledge creation. The previous research suggests that the likelihood of collaboration is still being increased by physical proximity even in the age of telecommunication and the Internet (Kraut, Fussell, Brennan, & Siegel, 2002), as it increases the frequency of communication and its duration. For instance, the study shows that researchers in the same department, which are physically close to each other, were more likely to collaborate than those in different departments, which are farther apart (Kraut, Egido, & Galegher, 1990). However, the proximity phenomenon no longer denotes only the distance between two objects, as it became truly multidimensional. A leading role in research utilizing the point of view that proximity is much more than just geography

belonged to the “Proximity Dynamics” group, which emerged in France in the beginning of 1990s and consisted of industrial and spatial economists, interested in space and in the subject of enterprise and organization respectively (Torre & Gilly, 1999).

According to Boschma (2005), there are five dimensions of proximity – geographical, organizational, social, institutional and cognitive, and each of these proximities can have both the positive and negative (in case there is too little or too much proximity involved) effects on interaction, cooperation, collaboration and learning. For instance, geographical proximity is defined as “spatial distance between actors, both in an absolute and relative meaning” (Boschma, 2005, p. 63) and contributes a lot to literally bringing people together, while the organizational proximity denotes sharing both spaces of relation and knowledge and is defined by Monge, Rothman, Eisenberg, Miller, & Kirste (1985) as “two or more people being in the same location where there is both the opportunity and psychological obligation for face-to-face communication” and as “actors whose interactions are facilitated by (explicit or implicit) rules and routines of behavior and that share a same system of representations, or set of beliefs” by Torre & Rallet (2005).

Even though all the dimensions of proximity are important to collaboration, in this paper we are focusing on *geographical proximity*, but in a different context and in a different environment. *We argue that the geographical proximity of children in the elementary school context makes a big impact on intragroup dynamics (for instance, level of stress) and on the degree of willingness for working together (collaborating) with other pupils*, as for those children the physical proximity is still one of the core elements of successful collaborative learning and the positive (or negative) attitude towards it. Previous research suggests that the face-to-face work - students’ relationships, group discussions and the ability to encourage and respect the contributions of others - is of high importance to the development of critical thinking skills and therefore has a direct impact on the development of students’ collaborative and cooperative learning skills (Bailin et al, 1999; Thayer-Bacon, 2000).

There are quite opposite points of view displayed in the literature on the importance of geographical proximity. For instance, Boschma (2005) claims that the geographical proximity in the modern world is “neither necessary nor sufficient condition” (Boschma, 2005, p.71), as other forms of proximity can serve as substitutes to solve challenges plus

“learning processes require at least cognitive proximity besides geographical proximity” (Boschma, 2005, p.71), which makes the geographical proximity not necessary and not sufficient respectively, whilst Werker & Cunningham (2011) states that geographical proximity “can be crucial for collaborations” (p. 9) and highlights the importance of functional closeness of actors, which, when it comes to economics, can exist on regional, national and global levels.

However, those papers mainly concern the grown-ups, who arguably had a better understanding of the values and benefits of collaboration (simply due to having more experience), shared knowledge and mutual benefits plus were able to use all the tools of communication on their own. When we move the concepts of proximity to the elementary school context, things can't remain the same.

This brings us to the question which effect will the geographical proximity have on the collaboration and mindset towards it, and on intragroup dynamics.

2.3 Usage of mobile instrumentation in the classroom

Mobile devices can give both the students and the teachers many opportunities for both studying and learning and offer a great potential. They enhance the studying experience for students and instruction possibilities for teachers while providing tools to both (Constantinidis et al, 2013).

According to Abrantes & Gouveia (2010), mobile devices are ubiquitous, which is one of their main advantages when compared to desktop computers. Due to their ubiquity, they give the users a chance to remotely get the information they need and stay connected.

The findings of previously carried out studies state that mobile technology is a potential learning tool which can enhance the students' learning experiences and raise the frequency level of engagement in learning activities outside of class (Kim et al, 2013). For example, Kim et al (2013) argue that the group of students having the mobile devices (as opposed to the group using mobile computers) tended to engage more with the mobile content and mobile communication services (messaging) due to the increase in intrinsic motivation.

However, the same study states that due to the small screen size and the operation-related challenges (typing in the text, uploading large files, logging in to message boards), most of the students using the mobile devices chose to switch to mobile computers for selected tasks (Kim et al, 2013).

A study about mobile learning by Corbell & Valdes-Corbell (2007) argues that mobile instrumentation and devices offer a chance of connecting classrooms with distant learners.

2.3.1 Measuring experiences via mobile devices in the classroom

Being a relatively new and partially unexplored topic, the impact of mobile devices in the research context is still a subject under study (Pinter, Toninelli & de Pedraza, 2015). The reason for that might be the fact that measuring students' experiences via mobile instrumentation and devices isn't yet as extensively used in the classrooms as e-learning.

However, the topic is getting more and more attention. Mobile devices prove to open up new possibilities for data collection - this aspect is a benefit not only for researchers but also for teachers, which could help to stay connected to students, receive valuable instant feedback and trace their progress better.

According to Scornavacca, Huff & Marshall (2009), interaction systems in the classroom can greatly benefit from the usage of mobile devices. Their study describes the introduction and implementation of short message services (SMS) to increase interactivity in a large, 1200-student undergraduate classroom, and analyses the impact of SMS implementation on learning experiences. The paper indicated that both the teachers and the students could benefit from an additional, new mobile device-provided communication channel. According to the authors, the students reported an increase in engagement and interest while appreciating the interactiveness of the instruction. The teacher, in his own turn, benefited from increased quality and quantity of feedback from students, who were using this new communication channel, which helped him to measure his students' experiences better.

According to Şahin & Mentor (2016), mobile assessment is highly beneficial for both formal and informal education, as it is available anywhere where learning happens.

According to their study, it could change how information is collected and provide assessment tools. Provided that mobile assessment is smartly used and smartly designed, it could help teachers learn as much as possible about their students' learning without cognitively overloading them or experiencing errors.

The increased portability of the mobile devices could be both an advantage and a disadvantage. Modern lightweight and compact devices carry around, but when it comes to in-class usage, the small size of mobile devices (such as screen size, poor connectivity and limited input modalities) has limited the ways the users can interact with them (Harrison, Flood & Duce, 2013).

2.3.2 Problems associated with using mobile devices for data collection and in the classroom

Along with the clear advantages of using the mobile devices for data collection, there are also a number of limitations and disadvantages. Among the most frequently mentioned problems are the unreliability of mobile networks (loss of signal and coverage), problems with keeping the devices charged (either due to mistakes or lack of access to electricity) (Ballivian, Azevedo & Durbin, 2015), and smaller screen and difficulties with typing (Kim et al, 2013).

Moreover, according to Trucano (2014), there are a number of disadvantages and challenges on top of the above mentioned ones: 1) Choice of technology (it's not always easy to decide which technology to use and how to make the right, most appropriate choice for your research); 2) Need of training and instruction (in some cases additional training connected to the usage of technology might be required to both the participants of the study and the researchers); 3) Cost (the development costs of digital, mobile instrumentation-friendly solutions could be more costly than for the traditional, paper-based studies); 4) Data security (risks connected to data security and privacy – additional agreements and arrangements defining terms and conditions and the actions in case of data breach are needed); 5) Speed of change (rapidly changing world of technology can influence data collections – especially the lengthy ones; new technologies emerge very

quickly and it's not always easy to take such changes into an account while planning lengthy research).

It's extremely important to never forget that the researchers should "first identify issues to be addressed, then identify the technology" (Trucano, 2014), not the other way around.

Besides, the issues which are not present in a certain part of the world can be very present in another part of the world (Trucano, 2014). That's a simple truth no one should ever forget, as the obstacles could be anything from the lack of electricity and absence of devices to the ban on using the mobile devices (or certain applications) coming from the government.

Last but not least, there's always the question whether to let the students use their own mobile devices in the classroom or not. There are studies reporting the positive effect of pupils using their own devices in the classroom with the effects of higher level of engagement and promoting the "differentiation of instruction" (O'Sullivan-Donnell, 2013), but the issue remains to be controversial due to the risk of pupils getting distracted by, for instance, their own personal messages on social media, internet browsing or games.

2.4 ESM usage in the classroom

The original purpose of ESM was not to study the classroom-related experiences such as the level of engagement or level of stress. The methodology was introduced to capture, measure and analyze day-to-day experiences and to study "what people do, feel, and think during their daily lives" (Larson & Csikszentmihalyi, 1983/2014). In a nutshell, ESM aims to study how people live their lives day to day and to understand individual subjective experiences as they are happening.

The method strives to get immediate answers from individuals when those individuals are asked to do so. The responses are written and both open- and closed-ended questions can be asked at a few or several points throughout the day, week or month. The individuals should receive a signal of some sort when it's time to provide the answers to the questions in ESM questionnaire – usually, the mobile device does the job (pager, mobile phone, etc). According to Hektner, Schmidt & Csikszentmihalyi (2007, p. 7), ESM combines "the

ecological validity of naturalistic behavioral observation with the nonintrusive nature of diaries and the precision of scaled questionnaire measures” where the distortions due to lack of retrospection are set to minimum.

Being a versatile technique with unique ability to directly capture daily life, ESM proved to be useful for studying a broad range of issues, such as the participants’ ”cognitive, emotional, and motivational states and their perceptions of their current social situation” (Larson & Csikszentmihalyi, 1983/2014, p. 23). The method was brought to the classroom context and started to be implemented into various classroom-related activities and research designs, thereby allowing researchers to better understand how experiences are being shaped by contexts and people. ESM grants researchers access to daily life-related data which is not available otherwise. According to Zirkel, Garcia & Murphy (2015), ESM is underused in education research and the broader use of it could enable researchers to broaden the scope of research, explore new ideas and make studies deeper. Access to experiences of educational actors (pupils, teachers, parents, etc) could give an additional dimension to any education-related research there is.

Colombo & Landoni (2014) used the ESM to measure the user experience of children using e-books, which makes their study methodologically similar to this one. However, a combination of technical problems and a lack of participant responses resulted in a relatively low response rate of 22% - due to participants not responding and technical errors. One more example study is the one by Turner et al. (1998) – the researchers combined ESM with observations of the classroom, examining the teacher’s instructional discourse with students and involvement.

2.5 Usage of teacher observation in the classroom

The teacher, while being in the center of the classroom during the lessons, is often the one who forms the groups his students will be working in. According to the study on group dynamics in primary school by McCarty (1953), at primary school context children should be properly studied by their teachers prior to grouping within the classroom, as the smart and appropriate grouping is one of the keys to successful group work. In order to determine the needs of each pupil, the teacher should keep track of the stages of their physical

development, physical condition, mental maturity, home background (with a goal of knowing something regarding their interests, appreciations, and attitudes outside of the classroom), and personality patterns (emotional response to certain situations, etc.). This indicates that the importance of teacher's observations can't be underestimated and the observations play a crucial role in teamwork even before the teams are formed and the teamwork starts. In the scripts where the teams are formed by the teacher, the teacher himself, as a team builder, has a huge impact on the result of teamwork.

In order to track the students' progress, teachers need to use a number of techniques to collect information to be able to properly facilitate and support their learning, to help, and to provide constructive feedback while assessing students both formally (exams, tests, theses, etc) and informally (notes, recordings, self-assessments, etc). Both formal and informal assessments have their advantages and disadvantages (McAlpine, 2002). Formal assessment is believed to have a smaller chance of bias while still being stressful to students (one of the reasons of underperforming) and not guaranteeing students having the deep understanding of subjects under study. Informal assessments, on the other hand, are believed to reduce stress level for students and provide a broader view on students' abilities. However, the assessor can fall a victim of prejudices and stereotypes.

Teacher's observations belong to the "informal assessment" category, which by default makes it a controversial assessment criterion. There are a number of arguments against teacher's observations stated in published works – lack of representativeness, lack of observation, control of influences, standardization, and objectivity. Also, there's reportedly the possibility of stereotyping and bias. Even though all those arguments are worth considering, some of the researchers argue that - if carried out correctly - information gained via observation of student performance makes the most useful source (Hermida, 2014)

The validity of the data obtained via observation highly depends on how well did the teacher document what he observed and if the teacher complemented his observations with evidence of the incident. Briefly describing what happened, the notes should be objective, not subjective – without conclusions included. Observation influences assessment, thus proper evidence should be collected and kept for assessment verification and validation purposes (Maxwell, 2001; Rencken, 1996).

Observation can be incidental or planned. Incidental is observation carried out when the unplanned opportunity emerges in the context of classroom activities of teaching and learning. Planned observation is a planned opportunity to observe “specific learning outcomes” (Maxwell, 2001, p.1).

Even though planned observation is at times useful for obtaining additional information or information of interest, the observation should be mostly incidental, because that’s when the observation is deeply embedded into learning processes and activities (Hermida, 2014; Maxwell, 2001).

According to Maxwell (2001), teacher observation contributes to assessment and makes it more: 1) comprehensive (taking all desired learning outcomes into an account – especially those assessable only in the classroom context, face to face); 2) connected (linked to curriculum, learning experience, and pedagogical planning); 3) contextualized (taking the context into an account and getting evidence from vast variety of situations and occasions); 4) authentic (holding a bigger meaning to students); 5) holistic (emphasizing the connectedness of all the processes in learning and offering the view on the whole).

Arguably, teacher’s observations can be just as important part of the assessment as the grades for written tasks, tests and other formal means of assessment included into the curriculum.

3. AIM AND RESEARCH QUESTIONS

The goal of this research is to carry out a multi-source data collection in authentic classroom environment using the mobile devices and instrumentation as the main data collection tool in order to use the minimum amount of tools to avoid interference.

The study aims to track and study the changes in intragroup dynamics along the whole duration of authentic collaborative project work, to study the impact of the geographical proximity of group members on intragroup dynamics, and to compare the data obtained from different sources to each other (ESM data, location data, teacher interview data).

In addition, the study discusses how mobile instrumentation in general and Experience Sampling Method (ESM) research methodology combined with the location tracking data can enhance the teacher's understanding of their students' progress, difficulties, and intragroup processes.

The research questions are:

- (1) How do different groups experience collaboration in the course of the project work?
- (2) Are there any discrepancies between teacher observations and student self-reflection via ESM?
- (3) How is the impact of geographical proximity on intragroup dynamics visible in the data collected via mobile devices, instrumentation, and sensors?

4. RESEARCH METHODS

4.1 Study Design

The study was conducted in February 2016 in Oulun Normaalikoulu (Oulu University Teacher Training School) in Oulu, Finland. The research team consisting of two people carried out an intervention with an aim to do data collection in authentic classroom setting without creating any specific conditions for data collection to ensure the authenticity of the study.

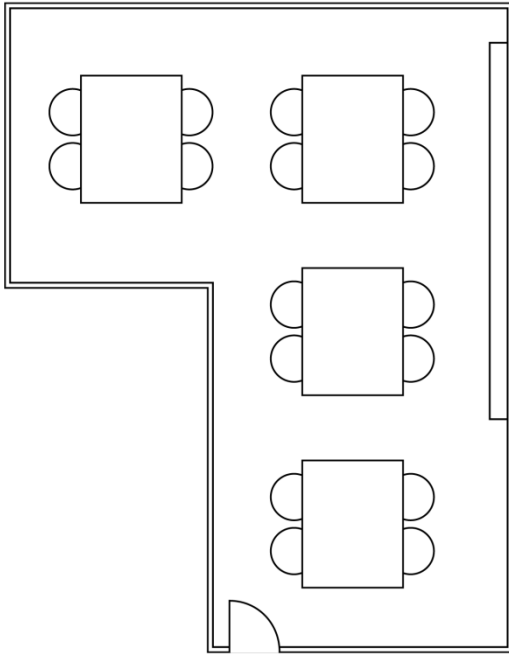
The data collection was carried out in the 5th grade with a total of 16 Finnish-speaking pupils. Prior to the study, the researchers prepared consent forms for all of the pupils, where the pupils had a choice to either agree or disagree to be a part of the study. Also, in case the given answer was positive, the form asked if the participants gave us the right to use the obtained material and present the results to the public. The pupils were given a few days to take the forms home, think about it and consult with their parents. After the forms were returned to the researchers and processed, it turned out that one of the students chose not to participate in the study, thus the total number of students involved was 15 ($n = 15$, age 10-11, 60% male). The students' names were replaced with general "Student 1"- "Student 15" labels to ensure the privacy of the participants.

The data was collected along the real "Tämä toimii!" ("This works!") 2015-2016 project (<http://www.luma.fi/tamatoimii/3995>), which was an authentic and demanding collaborative task with the total duration of 4 weeks. For this project work, the pupils were separated into four groups of four people by the teacher. Each of the groups had their own "workstation" – one big table for the whole duration of the project (Figure 1). The session on Week 1 (the 4th of February, 2016) was the introductory one, thus the data collection started on Week 2, which means there were three data collections in total (the 11th, the 18th and the 25th of February, 2016 – every Thursday three weeks in a row). The sessions lasted for approximately 4,5 hours each.

The students were grouped by the teacher according to his prior observations (McCarty, 1953). The teacher had an aim to create well-balanced groups with the better- and worse-achieving students in each.

Figure 1.

Layout of the classroom during the study.



The pupils' tasks included sharing responsibilities within a group, keeping a diary about the project and its progress, creating a moving educational toy, creating a poster and making a presentation of the final product.

This classroom and its students as a sample were chosen for this study for a number of reasons. The collaborative project work they were about to do was already a part of their curriculum, thus no specific conditions had to be artificially created for the study. Instead, the researchers could focus more on planning the study in a way that it interferes with the normal classroom design as little as possible and goes well with the planned project work. Moreover, the pupils in Oulun Normaalikoulu (Oulu University Teacher Training School) school have had experience in collaborative work prior to the project as the school has collaboration solidly integrated into the curriculum and classroom design, which was beneficial for our intervention. It gave the researchers possibility to focus on changes in emotions and motivation of the pupils caused by the collaborative work instead of changes

in emotions and motivation caused by gradually getting used to collaborative work.

The intervention was planned in close cooperation with the classroom teacher, as it wouldn't have been possible without him and his insights. The teacher implemented the study into the workflow and made sure it stayed there. The researchers weren't present along any of the data collections to minimize pupils' distraction and to make sure the teacher remained the main figure for the students in the course all the lessons. The research team was present in the classroom only in the beginning and end of each of the sessions - to set up the equipment and to pick it up respectively. Thus it was absolutely crucial to the teacher to know what the researchers were planning to do, how and when. For instance, the teacher told the pupils to launch the ESM questionnaires when the time was right and made sure the pupils didn't move the Bluetooth beacons installed by the researchers on each of the tables in the classroom. Last but not least, the teacher had to know precisely what the study is about so that he can observe students and their progress better, focusing on particular details. The teacher was aware that he was to be interviewed after the project work had ended.

4.2 Mobile devices and technology

Data collection was carried out using mobile devices (mostly Nexus 7 tablets) given out to each of the participants. Each of the devices had AWARE middleware framework for mobile sensing (Ferreira, 2013), locally developed in Oulu, pre-installed on all of them. AWARE is a mobile instrumentation toolkit and "an open-source effort to develop an extensible and reusable platform for capturing, inferring, and generating content on mobile devices" (Ferreira, Kostakos, & Dey, 2015, p. 1) and mobile context instrumentation middleware, leveraging hardware, software and human sensors to capture user experiences (Ferreira, 2013). Testing and using locally developed technology in the field was also one of the goals of this study.

In addition to AWARE, a separate own plug-in launching ESM questionnaires in one click set to work with AWARE was also pre-installed on all of the devices (Figure 2). The plug-in allowed the students to quickly launch the ESM questionnaires at the moments indicated by the teacher, which ensured all the students were answering the ESM questionnaires at

approximately the same point of the lesson. The plug-in was made to work on any Android device.

Figure 2.

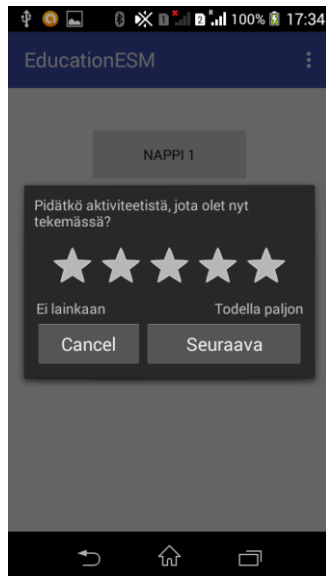
ESM plugin screenshot using the AWARE framework with 3 buttons to obtain the ESM answers from pupils in the beginning, middle and end of each of 3 sessions.



Thus, after receiving an alert from the teacher regarding which button to press, the pupils immediately saw the first question on the ESM questionnaire popping up on the screens of their mobile devices (Figure 3).

Figure 3.

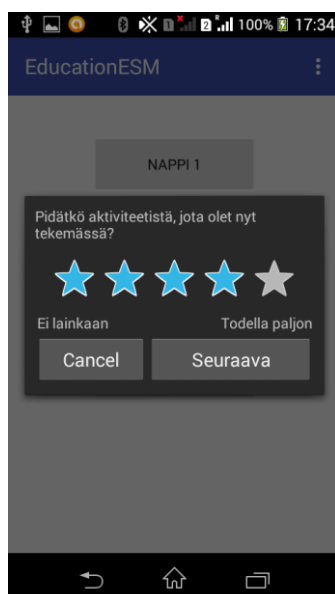
ESM plugin screenshot using the AWARE framework with the first question.



In order to make the answering process as easy as possible, the Likert scale was visualized as 5 stars (with the clarifications on the screen given for 1 and 5), thus the pupils were able to give their answers in just two clicks (Figure 4).

Figure 4.

ESM plug-in screenshot using the AWARE framework with the first question answered and ready to be submitted.

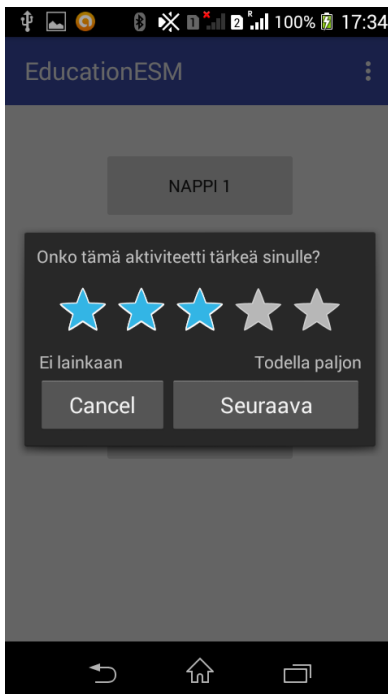


After the answer was given, the pupils clicked “Seuraava” (“Next”) to see the next question and answer it (Figure 5).

After the pupils clicked “Seuraava” (“Next”) after answering the last question of the questionnaire, the data containing their answers to all eight questions went directly to our server.

Figure 5.

ESM plug-in screenshot using the AWARE framework with the second question appearing right after the first one is answered.



To measure the participants’ experiences before, during, and after each session, we repeated the same questionnaire over the course of the whole study. The questionnaire focused on collaboration and project work and was once piloted on paper prior to the study to make sure all the participants understood the questions correctly. The pilot was required as ESM success usually depends on how genuine the given answers are, thus answering should feel natural and effortless (Hektner, Schmidt & Csikszentmihalyi, 2007).

In addition to using the mobile devices as a tool to collect ESM responses, they were also used in attempt to track the students’ location throughout the project work. Four unique

identifier signal-emitting beacons were set up in the classroom on each of four desks of the project groups (refer to Figure 1 for the classroom layout) and marked as beacons A, B, C, D for each of the four project groups. These beacons (KST Ion (Ion - KS Technologies, LLC) were configured to broadcast a Bluetooth signal containing their own unique ID. Bluetooth data was continuously collected throughout all the sessions. Participants' mobile devices continuously scanned nearby Bluetooth devices and stored both the Received Signal Strength Indicator (RSSI) values and beacon IDs. Using this information, we attempted to obtain an estimate of the relative distance between participants the beacons and the students. RSSI is a commonly used technique for indoor positioning.

4.3 Methods and Data collection

The questionnaire created for this study is based on the questionnaire developed by Csikszentmihalyi et al. (1993). That questionnaire was chosen as a benchmark as it had already been successfully used in the studies of a similar nature, which involved comparing students' experiences in the course of cooperative learning and collaboration (Peterson and Miller, 2004; Simpson, 2011).

The ESM method can measure: 1) the internal ("emotional, cognitive, and motivational aspects of consciousness" (Csikszentmihalyi et al., 1993, p. 54); and 2) external dimensions of experience (various settings – classroom, home, playground, etc.). However, our study didn't look at external dimension, as it is the same for all the participants of our study. While focusing only on internal dimensions, we looked at emotional and motivational dimensions of pupils.

The questionnaire used in this study had 8 questions in total, which asked the participants to self-report their level of enjoyment of the activities they were doing and of the group they were a part of, self-evaluate their success, motivation, and level of stress (Table 1). Responses were on a Likert-type scale, ranging from 1 to 5 ("Not at all" and "Very much" respectively). All the questions were presented to the students in Finnish. English translations are provided in this paper for the reference.

Table 1.

Questions of the ESM Questionnaire.

Question Number	ESM Question
1	Pidätkö aktiviteetistä, jota olet nyt tekemässä? (Do you like the activity you are doing?)
2	Onko tämä aktiviteetti tärkeä sinulle? (Is this activity important to you?)
3	Toivotko, että olisit tehnyt jotakin muuta sen sijaan? (Do you wish you had been doing something else?)
4	Onnistuuko sinulta hyvin se, mitä olet tekemässä? (Are you succeeding in what you are doing?)
5	Pidätkö ryhmätyöskentelystä? (Do you like working with the people in your group?)
6	Haluatko jatkaa työskentelyä ihmisten kanssa, jotka ovat nyt ryhmässäsi? (Do you want to continue working with the people in your group?)
7	Aiheuttaako tämänhetkinen aktiviteetti sinulle stressiä? (Is the current activity causing you stress?)
8	Aiheuttavatko ihmiset, joiden kanssa työskentelet, sinulle stressiä? (Are the people you're working with causing you stress?)

The ESM responses were collected with the plug-in developed for AWARE middleware framework for mobile sensing, locally developed in Oulu (Ferreira, 2013).

In order to align the ESM questions with the lesson plan, the teacher simply instructed pupils when to launch and complete each questionnaire on their mobile devices. The alerts from the teacher came approximately in the beginning, middle and end of each of the sessions – no exact same time for answering the questionnaires was set for all of the sessions to avoid the lesson interruption. The teacher instructed students to launch ESMs when he felt it won't interrupt the natural flow of pupils' work.

A total of 15 mobile devices were used – there was one specific device assigned to each of 15 participants. The devices were tagged with stickers to avoid confusion while giving them out to students and avoid giving a wrong device to a wrong student. Besides, the devices were assigned a device number at AWARE dashboard online and marked with the students' names.

Both the location and ESM data went to the AWARE server and were later exported for further analysis.

The classroom teacher was interviewed right after the “Tämä toimii!” project was finished. The goal of the interview was to obtain the information which ESM data couldn't give - which of the teams won the competition, if all of the teams managed to finish and hand in the task, if the students reported any discomfort connected to answering ESM questionnaires on mobile devices and teacher's comments on interpersonal communication between the group members. Besides, with the interview we aimed to determine which factors contributed to success and failure of all the groups (co-occurring factors). The teacher was familiar with eight ESM questions the researchers were asking from students, thus he was able to tweak his observations accordingly. In the course of 20-minute semi-structured interview, five questions were asked (Table 2) and notes were taken for further processing.

Table 2.

Teacher interview questions.

Question Number	Question to the teacher
1	Which of the four teams won?
2	Did all the teams manage to finish the project work and submit the task?
3	Which factors contributed to both the success and the failure of the groups?
4	Did the pupils report any discomfort connected to answering ESMs on mobile devices along the sessions?

5 Do you have any other comments on the project and team work?

The teacher observed and interacted with the students along all three sessions as their main and the only teacher in the classroom. Also, we strived to compare his observations with the data we got and to get an additional perspective before we write a qualitative explanation to numerical relationships given by the ESM data. That information is crucial to our experiment and it has to be taken into an account due to the competitive nature of the “Tämä toimii!” project.

5. DATA ANALYSES

5.1 ESM Analysis

With 15 as a total number of participants, ($n = 15$, age 10-11, 60% male) and ESM questionnaire consisting of 8 questions, which the participants were to answer a total of 9 times over 3 sessions, a total of 5236 ESM responses reached the server. Most of those responses were blank due to server- and network-related errors. After removing all the data-free ESM responses we had 1432 ESM answers left to analyze. After the removal of duplicate and blank ESM answers (the result of the data reaching the server multiple times), 965 ESM answers remained available for analysis (response rate of 89.3%). Presence of the teacher and allotted time slot to answer the questionnaire contribute to this high response rate.

The data overview and first analysis were carried out via R Studio via data visualization, where 3 questions of interest were identified based on the biggest differences in average group-by-group values (up to 30%.) and interest based on earlier analysis phases.

Next, for the second analysis in SPSS, the data was exported from the server and processed once again to make sure no variables got lost due to automatic filtering which was carried out via R Studio along the data overview and first analysis phase. First, the data which reached the server was exported to the computer for further processing as .csv file. Straight after export, the data was in single row format with no variables automatically identified, thus it had to be modified and coded before it could be processed. Only the necessary variables were left: ESM user answers (1-5), timestamps, student numbers, question numbers. Numeric timestamps were coded into the dd.mm.yyyy 00:00 format using R Studio. Device IDs were replaced with student numbers for convenience. Questions were changed to the basic question numbers (for instance, the first question, “Pidätkö aktiviteetistä, jota olet nyt tekemässä? (Do you like the activity you are doing?) was changed to a simple Q1). Last but not least, the data was sorted in Microsoft Excel using the “Custom Sort” function in three turns – first by the student, then by the timestamp and lastly by the question numbers. This way the data was more systematic and easier to be manually inserted to SPSS for further analysis.

In SPSS, the new dataset was manually created with an aim to carry out the mean comparison on the group level. The new dataset consisted of one numerical variable (name of the student replaced with the number) and 72 scale variables (ESM responses throughout all 3 sessions – 24 ESM answers per session).

The variables were assigned names, where X, Y and Z are the session numbers (sessions 1, 2 and 3 respectively) and T1, T2 and T3 are answers given in the beginning, middle and end of each of the sessions respectively. Thus, for instance, X5T1 stood for student's answer on ESM question number five given in the beginning of the session number one. For the full list of 72 scale variables please refer to *Appendix*.

Since a part of the user answers (10,7%) were missing from the server either due to technical errors or the pupils not finishing the questionnaires until the end and in order to have the complete dataset available for analysis, the “Missing Value Analysis” in SPSS was used to impute the missing variables into the dataset by estimating them. Expectation-maximization (EM) was used for this job, which is arguably one of the best methods to impute missing values in SPSS (Çokluk & Kayr, 2011). The procedure went without any errors occurring.

5.1.1 Principal Component Analysis

With an aim to check if and which of the factors and intragroup processes had the main influence on participants' answers throughout 3 sessions (if the variables are interrelated and to which degree), *principal component analysis*, a data reduction technique, was carried out via SPSS.

The aim of the analysis was to identify correlations between variables and come out with a maximum of 2-3 components per one answer round which do the job of explaining the correlations between variables our dataset has (as shown in *Appendix* of the present study).

The analysis was carried out using Factor analysis with Principal Components extraction and Varimax rotation. The analysis was done answer round by answer round – 8 questions (one full ESM questionnaire) at a time. For instance, the first round of variables inserted

for analysis included all the answers given to all 8 ESM questions during the first session's beginning (variables X1T1-X8T1).

All the rounds of variables returned valid results on Kaiser-Meyer-Olkin measure of sample adequacy (*greater than 0.5*) and resulted in SPSS defining from 2 to 3 components defined on the basis of Eigenvalues being greater than 1. The Bartlett test was significant (with a significance value $<.05$), meaning the variables are “correlated highly enough to provide a reasonable basis” for analysis (Leech, Barrett & Morgan, 2015). The only exception was KMO and Bartlett's test of sphericity for variables standing for the answers given to all 8 ESM questions during the first session's beginning (X1T1-X8T1), which had the low KMO value (0,475), which in that case was due to the fact that there are only two factors, and some items have a weak loading on one of them.

With the help of the Rotated Component Matrix table, showing the factor loadings for each variable and giving the possibility to point out the factor that each variable loaded most strongly on, we identified which factor generally had the most influence on teams' intragroup dynamics.

In order to look deeper into the factor identified by the analysis, which accounted for the biggest percentage of variability in all 8 variables in all answer rounds (and thus being one of the defining factors for students in every ESM answer round), paired samples t-test was carried out. Two different groups were selected according to the earlier analysis phases.

5.1.2 Paired Samples T-Test

Paired samples t-test is used to detect a difference between the means of two dependent variables.

In our study, a paired-samples t-test was conducted to compare the *drop in the willingness to continue working together in the end of the project work in non-succeeding groups with group member issues and succeeding groups* (groups were identified along the earlier analysis phases).

We analyzed the data from Groups 4 and 2, which were selected for this analysis according to the earlier analysis phases (group with issues with group members and the winning group respectively, as identified by the earlier analysis phases). The variables under study in our case are the first and the last time the group members answered the “Haluatko jatkaa työskentelyä ihmisten kanssa, jotka ovat nyt ryhmässäsi?” (“Do you want to continue working with the people in your group?”) question (variables X6T1 and Z6T3). The goal was to find out if we can reject the null hypothesis (if the probability of sampling error accounting for the results is $p \leq 0.5$).

Our sample size is 4 ($n=4$). However, each of those 4 participants was giving their answers to the ESM questionnaire consisting of 8 questions 3 times per session (with a grand total of 9 times during 3 sessions the data was collected throughout). Thus carrying out a paired samples t-test is possible (Student, 1908).

Our null hypothesis is: *the average difference score will be less than equal to zero*. It will be zero in case it would mean that the people in non-succeeding groups are just as eager to continue working together at the end of the project as in the beginning. It will be less than zero if the people in non-succeeding groups are more eager to continue working together at the end of the project as in the beginning.

Research hypothesis: *The average difference score will be greater than zero*, which will mean the people in non-succeeding groups are less eager to continue working together at the end of the project as in the beginning.

First, the paired samples t-test was carried out for Group 4. Paired Sample Statistics identified participants' answer average at the beginning and the end of the project work. After the paired samples t-test was carried out, it was checked if the mean is positive (meaning that the mean of participants' answers at the end of the project work is lower than at the beginning) and the statistical significance of the analysis was tested ($p \leq 0.5$, confidence interval doesn't include zero).

Next, the effect size of the test was investigated, which is given by the Cohen's d (small = .20, medium = .50, large = .80), using the following formula: Cohen's $d = (M2 - M1) / SD_{pooled}$, where: $SD_{pooled} = \sqrt{((SD1^2 + SD2^2) / 2)}$.

In order to support or reject (McLaughlin, 2006) our hypothesis, the same analysis in the same order was carried out for Group 2 with a goal to compare those results to the results obtained from the similar test carried out for Group 4 earlier. After the similar analysis was done, the results were compared for differences and the conclusion on our research hypothesis was made.

5.2 Teacher Interview Analysis and Comparing Two Data Sources for Differences

The teacher's interview was not transcribed entirely and, due to its brevity, wasn't recorded or videotaped. Instead, the notes were made, capturing the main points of teacher's answers on all five questions (Table 2). Later on the data was put to a table separated by categories (won, didn't win, had issues with group members), the processed version of which can be found in the Results section of the present study.

Teacher's response to interview question number 3 ("Which factors contributed to both the success and the failure of the groups?") was open coded separately and the superordinate and subordinate categories (along with the dominant category) were identified. 2 superordinate concepts were identified and the notes taken during the interview were color-coded (red and green for the first and the second of the superordinate concepts were used). Next, 10 subordinate concepts were identified.

In order to check if the data obtained from two sources - via ESM questionnaires from students and the data obtained from the teacher interview - has contradictions, the findings from both data sources were compared. The goal of the comparison was to see if the data obtained from one of the sources complement the data from other one or if there are discrepancies between them. We studied if the teacher observations (data obtained from teacher interview) report the same changes in intragroup dynamics as the students' self-reports (level of enjoyment and importance of the activity, increases and decreases in the level of motivation, degree of enjoyment of working together and working on a project, influence of group members on each other).

The students' responses to three ESM questions of interest, which were identified based on the previous stages of the analysis and the biggest differences in average group-by-group values (up to 30%), were visualized group by group, using the average values per group.

6. RESULTS

6.1 RQ1. How do different groups experience collaboration in the course of the project work, according to ESM data?

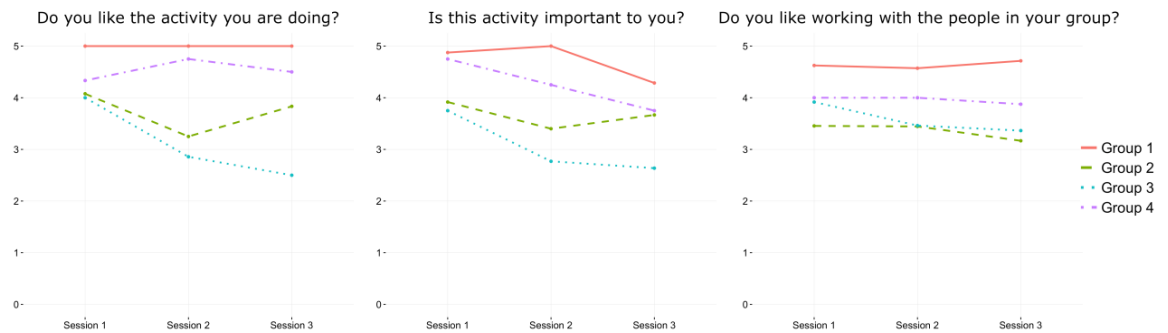


Figure 6. Average values of three ESM questions over the three different sessions for four different groups.

Figure 6 illustrates that the participants generally enjoyed working on the project and rated the importance of their current activity as high. For two student groups (Group 2 and 3), enjoyment and importance (first and second graph in Figure 6) of the activity seem to correlate. Project progress did not seem to drastically influence the participants working relationship (final graph in Figure 6) – the average for each of the groups was different, but the average on a group level was quite stable for all the groups throughout all 3 sessions.

By carrying out Principal Component Analysis we defined that the factor that generally had the most influence on teams' intragroup dynamics was the success of the project work. In all data rounds, 45-55% of Variance belonged to success-related variables, which means it accounted for 45-55% of the variability in all 8 variables. Thus this study argues that the success factor influenced the groups and their collaboration processes the most.

The link between the success factor, the most influential factor according to Principal Component Analysis, and students' willingness to continue working together was found. Our hypothesis that non-succeeding groups experience a bigger drop in willingness to continue working together in the end of the project than the succeeding groups is considered to be *supported* by our data. According to the Paired Samples T-Test, *the*

people in one of the non-succeeding group (Group 4) were significantly less open to continuing working together with their team mates at the end of the project work, $t(3) = 6,97$, $p = .006$, $d = 1.37$ (large effect size - the pupils from Group 4 at the end of the project work were 1.37 standard deviations lower in terms of their openness to continue working with their team mates than in the beginning), while the people in succeeding group (Group 2, the winning team) were relatively just as open to continuing working together with their team mates at the end of the project work, $t(3) = -1$, $p = .391$, $d = 0,23$ (small effect size- the pupils from Group 2 at the end of the project work were only 0,23 standard deviations higher (as opposed to 1.37 standard deviations lower in Group 4) in terms of their openness to continue working with their team mates than in the beginning of the project work).

6.2 RQ2. Are there any discrepancies between teacher interview data and student self-reflection via ESM?

We found that the data obtained in the course of semi-structured teacher interview doesn't always support (and at times does even contradict) the data obtained from the pupils via mobile devices using ESM methodology. A number of discrepancies regarding the students' level of enjoyment of working together, the influence of problematic group members on intragroup dynamics and students' motivation level were identified.

Table 3.

Summarized results of teacher's interview

Category/Group Number	1	2	3	4
Won	No	Yes	No	No
Finished	No	Yes	Yes	No

Issues with group members	Yes	No	Yes	Yes
Discomfort in answering ESMs	No	No	No	No

Table 3 shows the results of teacher's interview we carried out after the project work was finished. As the table illustrates, only two of the four groups managed to complete the project's task (groups 2 and 3). According to the teacher, the success of those groups was the result of different reasons. Group 2, who won the competition, had a strong and bright group leader who kept the group together. It's in line with the published research, which states that a team member can "play a leading role in activating motivation regulation" in the context of challenging socially shared learning (Järvelä, Järvenoja, and Veermans, 2008, p. 132). Group 3 had a surge of inspiration in the final project session and managed to leap forward and finish the work along the last session (i.e. during the last 4 hours of the project). Group 3 had one issue with one of the group members, who was holding the group back – according to the teacher, it "naturally" took a group a while to cope with this situation and get their motivation back. The teacher referred to that pupil as "problematic group member".

Groups 1 and 4 never finished the task. Group 1 had a good project idea and started highly enthusiastic, but lost motivation and got discouraged along the way due to an issue with one of the group members who had a negative influence on his peers, disrupting the atmosphere and slowing down the work. This problem is supported by the published literature: disruptive behavior of one student can lower general academic engagement and outcome of the whole group (Shinn et al, 1987). Group 4, although containing two very good members, did not finish due to similar problems. Those two members - the general "class leader", who created the whole idea, plus one very bright student – couldn't save the project task and make it work, as one of the group members was a "free rider" and did nothing at all. The teacher stated that this person was also the lowest achieving pupil in the class, which might be forced to stay in the 5th grade for the 2nd year. This group, according to the teacher, simply didn't click - for instance, the above mentioned bright

student, who usually does very well, simply didn't want to be in this group and thus didn't contribute as much as he could.

Neither of the groups reported any discomfort connected to answering ESM questionnaires on their mobile devices.

Table 4 provides the major results of the open coding analysis of the notes taken during the teacher's interview along him answering on question 3 ("Which factors contributed to both the success and the failure of the groups?"). The table shows 2 superordinate and 10 subordinate categories emerging from the analysis of teacher's response.

Table 4.

Categories emerging from the analysis of teacher's response "Which factors contributed to both the success and the failure of the groups?"

Major categories	Associated concepts
Failure	Problematic member, loss of motivation, discouragement, free rider, low achiever
Success	Group leader, motivation boost, good project idea, bright member, class leader

The dominant category most frequently referred to in the interview was the "problematic member". The teacher several times pointed out that those "problematic members", or underperforming pupils with behavior issues, were the main cause of some of the groups' failure and hardships. This is in line with the other interview data (Table 3), which shows that three out of four groups (75%) had members, who had a negative influence on their teammates.

If we compare the previously presented ESM data with the teacher's interview data, there are a number of things which are in line:

- 1) Increased level of enjoyment and importance of the activity of the winning team along session 3 - a sign of the work going well (Group 2, as visualized by green line on Figure 6);
- 2) Drop in motivation along session 3 for Group 1 (as visualized by the red line on Figure 6);
- 3) Drops in activity importance and the enjoyment in Group 4 – according to the teacher, the group didn't click due to the presence of free rider and two bright members not being willing to contribute much (as visualized by the purple line on Figure 6);

However, visible is a number of discrepancies between teacher interview data and student self-reflection:

- 1) Having the average from 3 to 4 in all 3 questions under study, the winning group (Group 2, as visualized by the green line on Figure 6), according to the data, didn't seem to enjoy working together and working on a project as, for instance, Group 1 (as visualized by the red line on Figure 6), which, according to the teacher, had an issue with one of the group members, who was disrupting the workflow;
- 2) Group 1, according to the teacher, had an issue with one of the group members. The data shows the opposite – the average of “Do you like working with the people in your group?” is the highest among all 4 groups and seemed to even go up a little bit in the course of the third session. However, it's worth noting that the data from Group 1 we have comes only from three members, as the above mentioned “problematic” group member chose not to participate in the study. Taking this into an account, we can state that the group members didn't seem to be negatively influenced by that, according to the teacher, “problematic” group member – at least not on a personal level (as visualized by the red line on Figure 6).

3) The teacher reported that the students in Group 3 got their inspiration back at the end of the work. The data contradicts that, showing the constant drop in all 3 questions (as visualized by the blue line on Figure 6).

4) Group 4, according to the teacher, suffered from one of the group members being a free rider, which even resulted in the bright members not being interested in contributing much. However, the participants seemed to be enjoying to work together – they have the second highest average and the averages along all 3 sessions didn't drastically drop (as visualized by the purple line on Figure 6).

6.3 RQ3. How is the impact of geographical proximity on intragroup dynamics visible in the data collected via mobile devices, instrumentation and sensors?

We found no clear link between students' geographical proximity data obtained via location tracking and their respective project success – mainly due to the location data being unreliable and incomplete (as further elaborated on in the Discussion section of the present paper). However, the effect of geographical proximity is to an extent visible in the context of intragroup dynamics. Both the ESM data and the teacher interview data shows that a number of students had effect – both positive and negative - on the rest of their group members (i.e. had an impact on the students' willingness to continue working together) simply by being in the group (i.e. physically close to other members) and, as a consequence, on project work's success and outcome. Negative influence and indifference of several pupils is suggested to serve as a cause of other students underperforming due to the loss of interest and motivation. The levels of both *willingness to continue working together* and the level of *being interested in the task they were doing* in such groups are gradually going down during all sessions.

7. CONCLUSIONS AND DISCUSSION

7.1 Main research findings of the empirical study in respect to the previous research

The aim of this research was to track and study the changes in intragroup dynamics along the whole duration of authentic collaborative project work using the mobile devices and instrumentation as the main data collection tool, to study the impact of geographical proximity of group members on intragroup dynamics and to compare the data obtained from three different sources to each other (ESM data, location data, teacher interview data). The results of the study brought answers to each of the three research questions. In this section, the results of the study are discussed in respect to earlier publications and findings. The significant part of the results of the empirical study supports previous research findings and contributes to the topics under discussion.

Firstly, the results show that all of the groups experienced collaboration differently because of number of factors which influenced the students and the flow of group work. Those factors could be identified using ESM methodology and our study illustrates that. Our results suggest there's a clear link between the project success factor, which influenced the answers to all the ESM questions the most, and students' willingness to continue working together, i.e. the higher the degree of project's success is – the more they want to continue working with the other people in their group. The degree of project work success was different for each of the groups, which had the direct impact on how the groups experienced collaboration and on intragroup dynamics. This is in line with the published literature, which states that the teamwork and its success are influenced and defined by a number of factors (Lai, 2011; Mattesich et al., 2001), which can be identified. This study suggests that the identification of such factors can be done using ESM methodology, underused in education research (Zirkel, Garcia & Murphy, 2015), and mobile devices and instrumentation as a tool for data collection. None of the participants of this study reported any discomfort connected to answering the ESM questionnaires on mobile devices, which supports the points of view that the usage of modern mobile devices in classroom could lead to increased level of engagement of students (Kim et al, 2013) and provide tools to teachers and researchers alike (Constantinidis et al, 2013; Şahin & Mentor, 2016; Scornavacca, Huff & Marshall, 2009).

Secondly, this study found that there are discrepancies between semi-structured teacher interview data and the self-report data obtained from the pupils via mobile devices using ESM methodology. Published literature supports the possibility of this happening, as it refers to teacher observation data (and, as a consequence, to teacher interview data) as informal assessment, which could be valuable, but at the same time could be subjective and biased (Hermida, 2014; Maxwell, 2001; McAlpine, 2002). Besides, this situation could have occurred due to the (disputed) “Hawthorne effect”, which causes participants of the study alter their behavior and reports due to their awareness of being observed, or due to the students thinking that their feedback wouldn’t have changed how the course is taught or improved their grade, which discouraged them from giving the quality feedback (Caulfield, 2007). The latter explanation makes sense as the pupils knew the data wasn’t collected by the teacher or the school staff, but by the 3rd party for research purposes only, which could have been the reason for both more and less honest answers. Social peer pressure among elementary school students could have had a large effect on student responses, too. The presence of those discrepancies highlights the complexity of collaborative processes and suggests that the deeper understanding of the factors influencing collaboration and project work can be gained via collecting and comparing the multi-source data for differences.

Thirdly, we found that both the positive and the negative effects of geographical proximity of the group members to one another are visible in the context of intragroup dynamics. This is in line with the published literature highlighting the importance of geographical proximity in the context of collaboration (Bailin et al, 1999; Kraut et al, 2002; Thayer-Bacon, 2000; Werker & Cunningham 2011). The findings of this study contradict point of view that geographical proximity in the modern age is “neither necessary nor sufficient condition” (Boschma, 2005, p.71) for successful collaboration. Location data could help the teachers and researchers understand intragroup dynamics phenomenon and complement the self-report data.

This study shows that the data collected from one source can either support or contradict the data collected from another one, but the sources should always complement each other by design i.e. provide an additional perspective for the study. The identified discrepancies between the teacher’s observations obtained in the course of the semi-structured interview and the students’ self-reports obtained via mobile devices using ESM methodology raises

questions on the validity of self-reports in educational settings as well as of the teacher observations. Thus the multi-source data can provide the researchers with additional view on the phenomenon under study and more possibilities for deeper analysis.

7.2 Further discussion, practical implications and conclusions

Mobile devices and instrumentation, if implemented and used correctly, can be used not only for multi-source data collections in the research of similar focus, but also to provide insights to the class teacher during day-to-day lectures. This study argues the mobile devices and instrumentation have a potential of enhancing teachers' understanding of their students' progress and difficulties by providing additional perspectives to phenomena under study. Data collected via mobile devices could be easier to handle and faster to process and analyze in comparison to the data collected on paper. Besides, it might help some of the pupils who are naturally uncomfortable with giving negative feedback to their teachers – mainly due to hierarchy or fear of negative repercussions – to submit more honest answers. The implementation of ESM methodology via mobile devices and instrumentation in the classroom, as shown by this study, could help the teacher identify the factors which have the strongest influence on pupils (and their success, failure, behavior, feelings, and mental state), analyze such factors and address them directly. In particular, better insights into intragroup dynamics along the whole duration of authentic collaborative project work could be obtained. Principal component analysis carried out as a part of this study with a goal to check if any of the behaviors and intragroup processes had the main influence on participants' answers throughout three sessions is an example of such approach. However, it's important to note that this study didn't aim to track changes in both external (settings) and internal (emotional, cognitive and motivational) dimensions of experience via ESM. While focusing only on internal dimensions, the paper studies emotional and motivational dimensions and changes they underwent. Besides, the paper was focusing on group-to-group comparisons and did not aim to compare individual pupils to each other. However, such comparison was touched upon to a certain degree along the study.

As mentioned in the present study before, in addition to the ESM data and teacher interview data, the location data was collected. It wasn't put into the spotlight of the study

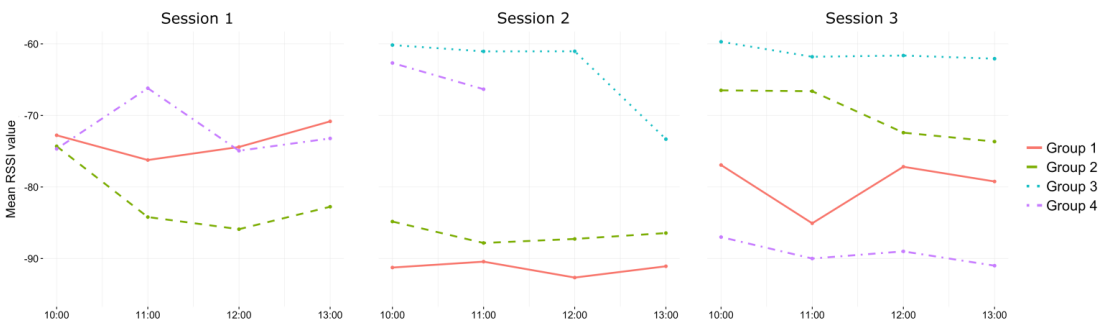
due it being incomplete and thus unreliable. Instead, it was chosen to discuss the outcome of the location data collection and state the observations, limitations and practical implications, which are presented in this section.

We deployed four beacons in the classroom at the center of each group's working table to track students' locations throughout all three sessions. The collected RSSI data of each of the participant's phone was to indicate the relative distance between a participant and the group's desk and their proximity to other group members.

Figure 7 shows the average RSSI value for each group over the duration of the study. As a result of students walking back and forth between their classroom and other rooms in the building (e.g., material room, lunch cafeteria), connection with the beacons was often lost. This is particularly clear in Session 2, where group 4 seems to almost disappear, most likely as the result of the project group continuing their work elsewhere. This highlights the importance of having strong enough network signal to avoid the data loss because of similar reasons.

Figure 7.

Average group distance to their respective classroom table.

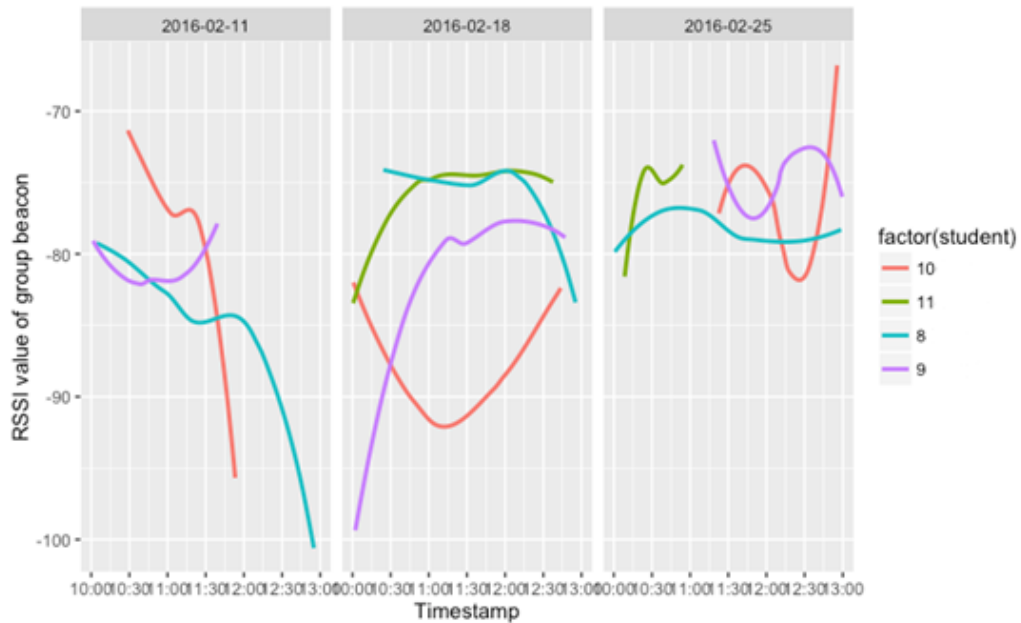


Missing RSSI data of group 3 in session 1 is likely the result of a technical problem during data collection. This problem highlights the importance of testing the equipment and the connection to the server, identifying the problems and troubleshooting them before the data collection.

Figure 8 displays the visualization of Group 3’s location data for three sessions (11th, 18th and 25th of February, 2016). The figure shows how close were the students to the beacon (and to each other, as they had an instruction to keep their devices with them at all times) at a certain time:

Figure 8.

Location data of Group 3 for all three sessions.



As we can see on Figure 8, the location signal was dropping from time to time or not present at all (e.g. Student 11’s device signal did not reach the server during the first session (the 11th of February) at all).

However, it’s visible that the group, according to the RSSI data, wasn’t always working together. This could have happened due to some of the students (i.e. student number 10 during the second session) choosing to work on their own at different locations or simply relocating with the whole group, leaving their devices behind. The latter case is one of the limitations of this study and it’s further discussed in “Limitations” section of this thesis.

Even though the location data collected throughout this study didn’t prove to be exactly useful in its incomplete form, this approach could be utilized in future research designs of the similar focus. The data obtained using this approach could complement data from other

sources and help draw conclusions after the ESM analysis is done. For instance, if there were visible patterns in the ESM answers of a particular student at points in time which could be identified, checking the locations of that student might help to make more solid assumptions regarding the cause of his or her answers. Also, the location data could show if the students were working all together (or at least were sharing a working space) or separately (on their own in different locations). Such an approach has a potential of serving as a proof of collaboration processes happening. The data could become more solid when combined with the data obtained via ESM questionnaires completed at the same time, which could give the researchers an insight into the subjective experiences of pupils as they were happening (Larson & Csikszentmihalyi, 1983/2014).

To sum up, the problems that may occur along the multi-source data collection using mobile devices, instrumentation and sensors in the elementary school classroom could be avoided by carrying out the pilot data collection, along which all the devices, instrumentation, software and the reliability of the networks are all tested and evaluated before the actual data collection starts. Such pilot data collection should be included into the research schedule to make sure there's enough time to identify and eliminate the technical difficulties, as technology plays a defining role in data collection of this sort. Our results suggest that the researchers should:

- (1) include the pilot data collection round to the plan of the study from the very beginning by making sure there is sufficient amount of time for it and that they have a permission to carry it out in addition to the actual data collection;
- (2) choose only the sources of data necessary for the research and make sure only the necessary data from those sources is chosen and collected. The researchers should make sure all the data collected complement each other by design i.e. provide an additional and needed perspective for the study;
- (3) avoid the public Wi-Fi networks due to their instability, as further discussed in the Limitations section of the present study;
- (4) pay special attention to the mobile devices and their physical size and weight - the more lightweight and compact the devices are – the better are the chances the students would keep the devices with them at all times, which increases the validity, accuracy and consistency of obtained location data;
- (5) make sure there's enough people in the research team to plan, set up and carry out the data collection.

This study is an early experiment on using mobile sensing to measure collaboration-related intragroup processes in a real, authentic classroom environment in the course of authentic project work. While the collected data is not perfect, the paper contributes to the issue of using the mobile devices and instrumentation in the classroom for research purposes, which is relatively fresh, challenging and unexplored topic.

We argue that the usage of mobile devices and instrumentation can provide the teachers and researchers with new insights in the classroom classroom-related processes, but both the technical and social obstacles that are unique to this context should be taken into an account before and during the data collection, and at all stages of data analysis.

7.2.1 Known limitations

The unique context and environment of an elementary school provided challenges which we wish to highlight in this section of the present study.

10,7% of the ESM answers and a part of location data didn't go to the server for purely technical reasons and (possibly) due to the students not responding to the ESM questionnaires until the end or not submitting it after they answered. We were using the public Wi-Fi network, which might have been the cause of the technical problems and signal drops. The latter especially concerns the location tracking data.

One of the main limitations of the study's data collection was lack of time and human resources. The researchers' team consisted of 2 people (the author of the present paper and the PhD student from University of Oulu). The confirmation that carrying out the data collection would be possible had been received not too long before the data collection had to start, thus the research team had an extremely limited amount of time to finish the research design and make all the necessary arrangements. The arrangements were to plan, prepare and give consent forms to students, to get those consent forms back and process them, to get all the necessary equipment for data collection, to plan and create the application for ESM for mobile phones, to install that application together with AWARE framework on all mobile phones, to run basic tests, and to agree on a plan with the classroom teacher and thesis supervisors. The data collected could have been better if the

researchers had more time to get ready for data collection and run all the necessary tests to make sure as many limitations as possible were avoided.

One of the students from Group 1 chose not to participate in the study. Thus the data from Group 1 was incomplete by default, entirely missing the data from one of the members, who was, according to the teacher, the one who negatively influenced his peers. It's highly unfortunate, as we can't study if his influence on the group and its work is visible in the data.

Last but not least, devices of students from groups 1, 2 and 3 were the Nexus 7 tablets. Even though those tablets are very compact and lightweight, it wasn't as easy for the students to keep the devices with them at all times as if they all had the mobile phones, which fit into almost any pocket. As previously mentioned, the preparations for data collection were done on a very short notice and due to local legislation and ethical issues, we were not able to provide participants with necklaces to carry the devices around without obtaining additional guardian consent. Having the smaller devices or the necklaces for tablets might have solved the problem of students leaving their devices on the tables when going out of the classroom and could have made our collected data more trustworthy. As the lessons in our case weren't videotaped, it was literally impossible to state if the pupil was at the table with the device at hand or left the room and left the device behind.

Future studies should consider the erratic, challenging and unpredictable nature of elementary school activities and environment to successfully capture as big of a part of the entire participant experience as possible.

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Appendix

A list of 72 coded variables used in the ESM data analysis

NAME OF THE VARIABLE	ITEM DESCRIPTION
X1T1	Question 1 (Pidätkö aktiviteetistä, jota olet nyt tekemässä? / Do you like the activity you are doing?) asked during session 1 for the first time.
X2T1	Question 2 (Onko tämä aktiviteetti tärkeä sinulle? / Is this activity important to you?) asked during session 1 for the first time.
X3T1	Question 3 (Toivotko, että olisit tehnyt jotakin muuta sen sijaan? / Do you wish you had been doing something else?) asked during session 1 for the first time.
X4T1	Question 4 (Onnistuuko sinulta hyvin se, mitä olet tekemässä? / Are you succeeding in what you are doing?) asked during session 1 for the first time.
X5T1	Question 5 (Pidätkö ryhmätyöskentelystä? / Do you like working with the people in your group?) asked during session 1 for the first time.
X6T1	Question 6 (Haluatko jatkaa työskentelyä ihmisten kanssa, jotka ovat nyt ryhmässäsi? / Do you want to continue working with the people in your group?) asked during session 1 for the first time.
X7T1	Question 7 (Aiheuttaako tämänhetkinen aktiviteetti sinulle stressiä? / Is the current activity causing you stress?) asked during session 1 for the first time.
X8T1	Question 8 (Aiheuttavatko ihmiset, joiden kanssa työskentelet, sinulle stressiä? / Are the people you're working with causing you stress?)

- asked during session 1 for the first time.
- X1T2 Question 1 (Pidätkö aktiviteetistä, jota olet nyt tekemässä? / Do you like the activity you are doing?) Asked during session 1 for the second time.
- X2T2 Question 2 (Onko tämä aktiviteetti tärkeä sinulle? / Is this activity important to you?) asked during session 1 for the second time.
- X3T2 Question 3 (Toivotko, että olisit tehnyt jotakin muuta sen sijaan? / Do you wish you had been doing something else?) asked during session 1 for the second time.
- X4T2 Question 4 (Onnistuuko sinulta hyvin se, mitä olet tekemässä? / Are you succeeding in what you are doing?) asked during session 1 for the second time.
- X5T2 Question 5 (Pidätkö ryhmätyöskentelystä? / Do you like working with the people in your group?) asked during session 1 for the second time.
- X6T2 Question 6 (Haluatko jatkaa työskentelyä ihmisten kanssa, jotka ovat nyt ryhmässäsi? / Do you want to continue working with the people in your group?) asked during session 1 for the second time.
- X7T2 Question 7 (Aiheuttaako tämänhetkinen aktiviteetti sinulle stressiä? / Is the current activity causing you stress?) asked during session 1 for the second time.
- X8T2 Question 8 (Aiheuttavatko ihmiset, joiden kanssa työskentelet, sinulle stressiä? / Are the people you're working with causing you stress?) asked during session 1 for the second

time.

X1T3 Question 1 (Pidätkö aktiviteetistä, jota olet nyt tekemässä? / Do you like the activity you are doing?) Asked during session 1 for the third time.

X2T3 Question 2 (Onko tämä aktiviteetti tärkeä sinulle? / Is this activity important to you?) asked during session 1 for the third time.

X3T3 Question 3 (Toivotko, että olisit tehnyt jotakin muuta sen sijaan? / Do you wish you had been doing something else?) asked during session 1 for the third time.

X4T3 Question 4 (Onnistuuko sinulta hyvin se, mitä olet tekemässä? / Are you succeeding in what you are doing?) asked during session 1 for the third time.

X5T3 Question 5 (Pidätkö ryhmätyöskentelystä? / Do you like working with the people in your group?) asked during session 1 for the third time.

X6T3 Question 6 (Haluatko jatkaa työskentelyä ihmisten kanssa, jotka ovat nyt ryhmässäsi? / Do you want to continue working with the people in your group?) asked during session 1 for the third time.

X7T3 Question 7 (Aiheuttaako tämänhetkinen aktiviteetti sinulle stressiä? / Is the current activity causing you stress?) asked during session 1 for the third time.

X8T3 Question 8 (Aiheuttavatko ihmiset, joiden kanssa työskentelet, sinulle stressiä? / Are the people you're working with causing you stress?) asked during session 1 for the third time.

Y1T1 Question 1 (Pidätkö aktiviteetistä, jota

- olet nyt tekemässä? / Do you like the activity you are doing?) Asked during session 2 for the first time.
- Y2T1 Question 2 (Onko tämä aktiviteetti tärkeä sinulle? / Is this activity important to you?) asked during session 2 for the first time.
- Y3T1 Question 3 (Toivotko, että olisit tehnyt jotakin muuta sen sijaan? / Do you wish you had been doing something else?) asked during session 2 for the first time.
- Y4T1 Question 4 (Onnistuuko sinulta hyvin se, mitä olet tekemässä? / Are you succeeding in what you are doing?) asked during session 2 for the first time.
- Y5T1 Question 5 (Pidätkö ryhmätyöskentelystä? / Do you like working with the people in your group?) asked during session 2 for the first time.
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- Y7T1 Question 7 (Aiheuttaako tämänhetkinen aktiviteetti sinulle stressiä? / Is the current activity causing you stress?) asked during session 2 for the first time.
- Y8T1 Question 8 (Aiheuttavatko ihmiset, joiden kanssa työskentelet, sinulle stressiä? / Are the people you're working with causing you stress?) asked during session 2 for the first time.
- Y1T2 Question 1 (Pidätkö aktiviteetistä, jota olet nyt tekemässä? / Do you like the activity you are doing?) Asked during

session 2 for the second time.

- Y2T2 Question 2 (Onko tämä aktiviteetti tärkeä sinulle? / Is this activity important to you?) asked during session 2 for the second time.
- Y3T2 Question 3 (Toivotko, että olisit tehnyt jotakin muuta sen sijaan? / Do you wish you had been doing something else?) asked during session 2 for the second time.
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- Y7T2 Question 7 (Aiheuttaako tämänhetkinen aktiviteetti sinulle stressiä? / Is the current activity causing you stress?) asked during session 2 for the second time.
- Y8T2 Question 8 (Aiheuttavatko ihmiset, joiden kanssa työskentelet, sinulle stressiä? / Are the people you're working with causing you stress?) asked during session 2 for the second time.
- Y1T3 Question 1 (Pidätkö aktiviteetistä, jota olet nyt tekemässä? / Do you like the activity you are doing?) Asked during session 2 for the third time.
- Y2T3 Question 2 (Onko tämä aktiviteetti

- tärkeä sinulle? / Is this activity important to you?) asked during session 2 for the third time.
- Y3T3 Question 3 (Toivotko, että olisit tehnyt jotakin muuta sen sijaan? / Do you wish you had been doing something else?) asked during session 2 for the third time.
- Y4T3 Question 4 (Onnistuuko sinulta hyvin se, mitä olet tekemässä? / Are you succeeding in what you are doing?) asked during session 2 for the third time.
- Y5T3 Question 5 (Pidätkö ryhmätyöskentelystä? / Do you like working with the people in your group?) asked during session 2 for the third time.
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- Y7T3 Question 7 (Aiheuttaako tämänhetkinen aktiviteetti sinulle stressiä? / Is the current activity causing you stress?) asked during session 2 for the third time.
- Y8T3 Question 8 (Aiheuttavatko ihmiset, joiden kanssa työskentelet, sinulle stressiä? / Are the people you're working with causing you stress?) asked during session 2 for the second time.
- Z1T1 Question 1 (Pidätkö aktiviteetistä, jota olet nyt tekemässä? / Do you like the activity you are doing?) Asked during session 3 for the first time.
- Z2T1 Question 2 (Onko tämä aktiviteetti tärkeä sinulle? / Is this activity important to you?) asked during

session 3 for the first time.

Z3T1 Question 3 (Toivotko, että olisit tehnyt jotakin muuta sen sijaan? / Do you wish you had been doing something else?) asked during session 3 for the first time.

Z4T1 Question 4 (Onnistuuko sinulta hyvin se, mitä olet tekemässä? / Are you succeeding in what you are doing?) asked during session 3 for the first time.

Z5T1 Question 5 (Pidätkö ryhmätyöskentelystä? / Do you like working with the people in your group?) asked during session 3 for the first time.

Z6T1 Question 6 (Haluatko jatkaa työskentelyä ihmisten kanssa, jotka ovat nyt ryhmässäsi? / Do you want to continue working with the people in your group?) asked during session 3 for the first time.

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Z8T1 Question 8 (Aiheuttavatko ihmiset, joiden kanssa työskentelet, sinulle stressiä? / Are the people you're working with causing you stress?) asked during session 3 for the first time.

Z1T2 Question 1 (Pidätkö aktiviteetistä, jota olet nyt tekemässä? / Do you like the activity you are doing?) Asked during session 3 for the second time.

Z2T2 Question 2 (Onko tämä aktiviteetti tärkeä sinulle? / Is this activity important to you?) asked during session 3 for the second time.

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- Z4T2 Question 4 (Onnistuuko sinulta hyvin se, mitä olet tekemässä? / Are you succeeding in what you are doing?) asked during session 3 for the second time.
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- Z7T2 Question 7 (Aiheuttaako tämänhetkinen aktiviteetti sinulle stressiä? / Is the current activity causing you stress?) asked during session 3 for the second time.
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Sergei Kopytin

Oulu, Finland

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